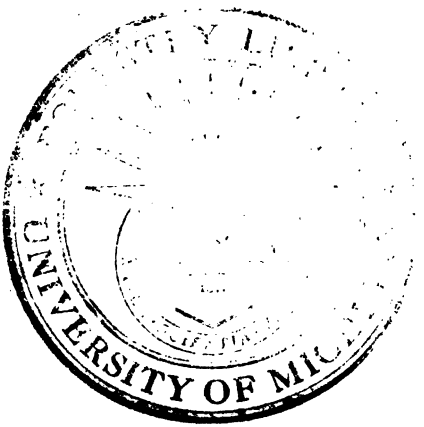
UNIVERSITY OF MI

ELEMENTS

OF

SYLVICULTURE.

ELEMENTS

OF

SYLVICULTURE:

A SHORT TREATISE ON THE

SCIENTIFIC CULTIVATION OF THE OAK AND OTHER HARDWOOD TREES.

BY THE LATE G. BAGNERIS,

INSPECTOR OF FORESTS, PROFESSOR AT THE FOREST SCHOOL OF NANCY.

TRANSLATED FROM THE FRENCH (2nd EDITION).

BY

E. E. FERNANDEZ AND A. SMYTHIES, B.A.,

INDIAN FOREST SERVICE.

LONDON:

WILLIAM RIDER AND SON,

14, BARTHOLOMEW CLOSE.

SIMPKIN, MARSHALL, & CO., STATIONERS' HALL COURT, E.C.

1882.

TRANSLATORS' PREFACE.

It may be objected that this book, being written only with reference to the conditions of soil, climate and species peculiar to France, possesses no value for Foresters in other countries where these three elements may be different. That this objection is only partially true, is so evident that very few words are necessary to justify the present publication. The broad principles of forestry remain the same everywhere, they are, so to say, mathematical constants. Heat, oxygen, and moisture are always essential for germination; young plants will invariably die if deprived of the amount of sunlight they require; inferior associated species of more rapid growth must be kept down by means of cleanings, &c., &c. These instances may be indefinitely multiplied. Even the chapters specially devoted to the treatment of the French forest trees, to which the above objection, if it has any force at all, applies in its fullest extent, even those chapters are not without their interest and use. The oak, the beech, the silver fir, the Scotch fir, and their peculiar

habits, are hard unalterable facts, data supplied by Nature. What is the best treatment for each of those trees? This question has been fully resolved by close, skilful and practical observers. Is a study of their answers and the processes by which these answers have been arrived at quite unprofitable? In a word, this work written only for the benefit of French foresters, contains not only the fundamental principles of Sylviculture, which remain true at all times and in all places, but also sound applications of these principles in special cases, which cannot fail to possess both interest and utility for their professional brethren in other climes.

We do not, however, wish our meaning to be misconstrued, and for this reason it is well to speak out plainly. The method of natural reproduction by seed is the backbone of modern French forestry, as indeed will be gathered to some extent from a perusal of the present publication, and those who would see for themselves to what perfection the method may be brought under a favourable climate and with enlightened supervision, have only to pay a visit to the more important State forests in France.

The State forests in that country have now been worked on some sort of a regular system for nearly 200 years, and during the last fifty years of this period the special wants and habits of forest trees have been made the subject of patient and intelligent

study. Thus the results arrived at are the fruit of inquiry extending over a considerable period, and embrace a vast array of carefully ascertained facts.

The lessons derived from a study of these facts are embodied in the present volume. It is a melancholy satisfaction to us to record the pleasure we experienced at hearing these lessons explained by the author himself, whether in the lecture room or in the field. The teacher has passed away, but his work remains, and if we have succeeded in rendering this clear and intelligible, our object will have been attained.

A word now with respect to the technical terms employed. Some of these are already current, and have been adopted by general consent; these it would have been unwise to alter: others though also expressing ideas of every day necessity, are entirely new, either because no word existed previously to denote these ideas, or because those at present in use are not sufficiently accurate or expressive. It is not necessary to enumerate here the reasons which in our opinion justify the adoption of these new terms. We would ask our readers to think of the importance of the subject-matter, rather than to dwell upon the imperfections of the translation.

E. E. FERNANDEZ.
A. SMYTHIES.

AUTHOR'S PREFACE.

The creation of superior schools for the training of forest subordinates has originated the Manual which I now offer to the public. It has been written with a view to bringing together in a compact form the various notions on forestry, restricting that term to Sylviculture properly so called. Hence I have abstained from discussing the economical questions which form the basis of Forest organization. I have similarly passed over in silence the exploitation or working of forests, felling excepted, which has so great an influence on the reproduction of coppice. It cannot be denied that the treatment of a forest is intimately connected with its Administration ; still it is not necessary to master thoroughly the laws of production and yield in order to learn how to carry out a regeneration cutting, a thinning, or a coppice cutting.

While seeking to convey only elementary notions, while writing specially for the benefit of Forest subordinates, I have not overlooked the points which

have appeared to me to constitute a real progress in Forest knowledge.*

I have followed the order of subjects prescribed by the programme drawn up in execution of the Ministerial Resolution of 8th April, 1870. An extract from this programme is given lower down in so far as concerns Sylviculture.† I have above all studied to be brief, so as to give all the greater prominence to questions of importance. Have I succeeded at the same time in being clear?

Such as it is, I commit this Manual to the judgment of my comrades, whose criticism I shall receive with gratitude, happy if I have been of any use to Officers and subordinates, as well as to proprietors and managers of estates.

* The chief of these is undoubtedly the theory as to the quantity of reserves to be left in a coppice with standards, which theory the Author was the first to formulate in a definite manner and to support on the authority of the Forest code itself, whose provisions on this head had, previous to this, been entirely misunderstood.

† The programme has been omitted in this translation, as it can have no interest for the general reader.

CONTENTS.

PART IV.

CHAPTER I.

CHAPTER II.

PART V.

PART VI.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

SUPPLEMENT.

ELEMENTS OF SYLVICULTURE.

PART I.

DEFINITIONS AND GENERAL IDEAS.

SYLVICULTURE is the whole body of observed facts which relate to forest vegetation, arranged and combined into a system in so far as they apply to the treatment of forests. Like everything else that is based on observation, sylviculture is essentially a progressive art; but every rational method of working forests must necessarily have as its objects:—*a steady yield, natural reproduction,* and *constant improvement of the produce.*

DEFINITIONS.—*Climate* is the state of the atmosphere at a particular place on the earth, as regards the temperature, the intensity of light, the amount of humidity, and the prevailing winds.

The *situation* of a place is its position relatively to its height above the sea (elevation), considered in connection with the configuration of the earth in that place.

The *aspect* of any tract is the direction (point of the compass) in which it slopes.

By *topsoil* we mean the upper layer of the earth attainable by the roots of plants, without any reference to its composition; differences in its composition give rise to the various soils we meet with

Vegetable mould is that portion of the topsoil which is formed by the more or less decomposed débris of organised matter.

The term *species* is defined as a group of individuals which resemble one another and their parents, and produce new individuals resembling them in all essential characters.

A *tree* is a woody plant with a single stem, leafless below, and capable of attaining a height of at least 20ft.

The words *shrub* and *bush* are used to designate woody plants that do not attain this height, and whose stem is branched from the base itself.

A *seedling* is a plant produced directly from the germination of a seed; a *shoot* springs up on a stool after the stem has been cut down; a *sucker* is a plant that takes its origin from somewhere along the course of a root.

Plants or trees standing together, whatever be their origin, are collectively called a *crop;* this term, however, is generally restricted to a collection of seedlings, and is not used for a collection of shoots or suckers, which is more specially termed *aftergrowth*.

The shoots standing together on the same stool receive the collective name of *clump*, and by *cutting back* is understood the operation of cutting down young stems close to the ground in order to make them shoot up from the stool.

A *rotation* is the number of years determined upon for the successive regeneration of an entire forest.

When the rotation is long, it is divided into parts generally equal, called *periods*.

The distinction between two *systems* lies in the method of reproduction adopted, whether by seed or by shoots.

In the same system, there are different ways of working the forest; hence the various *methods of treatment.*

A *working circle* is a certain extent of forest, intended to furnish a succession of cuttings during the whole length of the rotation, and which is sufficiently homogeneous with regard to soil, climate and species, to admit of one and the same system, the same method of treatment and the same rotation. It is termed *regular* when in addition the various crops composing it are of graduated ages, and each age is equally represented.

A portion of a working circle intended to be regenerated in the course of one period is called a *periodic block*; there are as many blocks in a working circle as there are periods in the rotation, and they should be constituted so as to yield, as far as possible, equal quantities of produce.

A *high forest* is a forest composed of seedlings, whatever be their age; its object, generally speaking, is to yield large timber, and its reproduction is effected by seed. A *coppice* or *copse* is a forest the reproduction of which is effected chiefly by means of shoots or suckers.

A forest is said to form *leaf-canopy*, when the crowns of the trees touch each other without being swayed about by the wind.

There are various stages of leaf-canopy depending upon the age and size of the trees that compose it,

and each stage has its own particular name. Thus, the forest is in the *thicket* stage when formed of young trees which still retain all their branches. It is in the *sapling* stage when the bole begins to form by the fall of the lower branches and while the diameter of the stem is less than four inches. When the diameter of the stem at the foot of the young tree varies from four to eight inches, the forest is said to be in the *low pole* stage. From this time it is termed *high poles* until the trees have almost attained their full length of bole. And when the trees have almost attained their full size in diameter, it is called *old high forest.* Although these various terms are more especially applicable to high forests, they are by usage equally applied to coppice; only care must then be taken to add the words *on stools.*

With regard to its denseness, a homogeneous crop is said to be *complete* when it forms a continuous leaf-canopy; if it is not homogeneous, it is said to be complete when the trees which compose it entirely cover the ground. The crop is *dense* when the branches interlace, and *open* when the crowns only touch one another here and there. When the crowns are isolated, the crop is said to be *discontinuous* or *interrupted.*

A *regular* crop is one which is complete and composed of trees best suited to the soil and climate and in which all promising trees are growing up under favourable conditions.

An *open glade* is a portion of a forest where the trees are few and far between and the soil is bare, or covered with inferior species. A *blank* is an open

glade without the trees. If the glades or blanks occupy extensive areas, they are termed *bare wastes.*

The designation of *white woods* or *soft woods* is given to those species which have a low density and a soft texture. Only four genera are included in this category, viz., *alders, limes, poplars,* and *willows.* In contradistinction, the other broad-leaved species form the category of *hardwoods.*

The term *brushwood* is applied to woody plants of small size and inferior quality, and includes the *elders, hazel, cornel-trees, privet, viburnums, spindle-tree, thorns, holly, juniper,* besides others.

When part of a forest is cut over, the trees allowed to remain standing in this portion are called *reserves,* and collectively they form the reserve of the area cut.

When no reserves are left in this area, the operation is termed a *clear cutting.*

The *underwood* is the young crop growing up underneath the reserves.

Windfalls are trees broken off or uprooted by any cause whatsoever, in the majority of cases by the wind.

By the term *cover* is to be understood either the vertical projection of the crown of the tree on the ground, or the action of the crown on the surface of projection. Cover acts by intercepting light and rain, and by preventing the formation of dew. Cover is injurious, and must not be confounded with shelter.

The term *shade* is applied in the same manner either to the surface of the ground actually shaded, or to the action of this shade. This action has the effect of temporarily lessening evaporation from the

leaves, or from the soil, and intercepts the direct rays of light. Shade, less injurious than cover, is useful only so far as it affords shelter.

To *exploit* a forest or crop means to fell it in accordance with the principles of Sylviculture.

A forest is *exploitable* when it has attained the maximum of utility for its proprietor. The state of a forest in which this condition has been realised is expressed by the word *exploitability*.

By *annual yield* is meant the quantity of produce that can be taken out of a forest annually while maintaining the production at a constant figure.

GENERAL IDEAS.

CLIMATE.—Climate is used in two senses: first, the geographical climate, which depends on the latitude, and secondly, the physical or local climate, which depends chiefly on the situation and aspect of the place in question. The distribution of the various species over the face of the earth is the principal result of the first kind of climate; for the forester it has only a general, though very important, interest. The second, while also influencing the distribution of plants, has a more direct action on the growth and quality of timber, and requires a short explanation.

On situation, which involves the idea of the configuration of the earth, rests the difference between the climate of plains and that of mountains.

CLIMATE OF PLAINS.—For a given latitude the climate of plains is generally more uniform than

that of mountains. It varies with the elevation of the plain, the nature of the soil, the proximity or remoteness of the sea and of mountain chains, as well as with the direction of the latter; it is further modified by the presence or absence of large sheets of surface water, and of forests.

Surface water by its evaporation lowers the temperature in summer. As it cools down slower than the atmosphere, it may diminish the cold at the beginning of winter; but once in a solid state, its more active radiation adds to the severity of the cold. Finally, in the spring it absorbs heat slowly, and thus too it lowers the temperature. Watery vapour in the shape of fogs intercepts the solar rays, and is apt to bring on frost. The presence of surface water renders the atmosphere moist, and lastly it opposes no obstacle to the wind, which thus retains all its force.

Although forests prevent the evaporation of water by the action of their cover, still their foliage diffuses much watery vapour into the atmosphere, and thus the temperature is lowered during the season of vegetation. In winter they impede terrestrial radiation and in consequence diminish the intensity of the cold. But a series of experiments not yet completed, proves that the mean annual temperature is rather less inside the forest than it is outside, and tends to show that the effect of forests as regards heat, is chiefly to prevent and to lessen sudden changes of temperature. The atmosphere contains more humidity in wooded countries than in places which are denuded of forest vegetation; it rains

there more frequently, and perhaps in greater abundance. Finally, forests, by presenting a barrier to the wind, break its force. They certainly act in other ways on the climate, but this action is not yet sufficiently understood, and it would be premature to go into the question here.

The elevation of plains chiefly affects the temperature; thus, in France, 330 feet of elevation have the same influence as one additional degree of latitude; that is, the effect is to lower the temperature by half a degree centigrade.

The nature of the soil is not without its influence on the temperature and humidity of the atmosphere. A free soil, by permitting the infiltration of water, gives off less watery vapour and thus increases the temperature; a stiff soil, produces the contrary effects. The darker the colour of the soil, the higher will be the temperature.

The proximity of the sea tends to equalize the annual temperature, increases the amount of moisture in the air, and allows full play to the violence of the winds.

Lastly, mountain chains, according to their direction, exert an influence on the temperature and the humidity of the atmosphere, and break the force of aerial currents.

CLIMATE OF MOUNTAINS.—The climate of mountains varies chiefly with elevation and aspect, result of the configuration of the surface, while still remaining subject to the same modifying causes as the climate of plains.

As one gets higher and higher, the air becomes

cooler, and drier (generally at least), and winds are more violent. This is equivalent to saying that forest vegetation, which was vigorous enough in the valleys, is less active on hill slopes, and becomes sluggish, and even disappears altogether, on high unsheltered plateaux. The shape of the trees too becomes deformed. But it is impossible to define sharply the climate of valleys and of slopes, because it depends entirely on the direction of the valleys, and thus each case must be examined on its own merits.

INFLUENCE OF ASPECT.—The influence exercised by aspect on the climate and the necessity of studying its action on the growth of trees, have already been foreshadowed in what precedes.

A *northern* aspect receives no sun ; on this aspect therefore there is but little heat, and the light is diffused ; the winds are cold, contain little moisture, and are seldom strong. But on account of the low temperature, the soil remains ever moist ; growth is therefore rapid, the trees are regular in shape, but the woody tissue is soft and not well lignified. Timber grown on this aspect is unsuited for building wood, but on the other hand well adapted for manufacturing purposes, especially for planking.

On an *eastern* aspect the sun shines obliquely and during the coolest hours of the day ; the temperature and the light on this aspect are therefore moderate, the wind is dry, and not violent. Under these conditions the soil retains its moisture fairly well, the growth is active, the trees are regular in shape, and yield timber of average quality, useful for all

purposes. The eastern is the most favourable aspect for forest vegetation.

On these two aspects, especially on the northern, the vegetation being tardy escapes spring frosts, but the shoots of the year which are not sufficiently lignified when autumn comes on, are apt to suffer from early frosts.

On a *southern* aspect the sun shines almost all day long, the temperature is high, and the light intense in its action; the winds are strong, and are often accompanied by storms and torrents of rain, which thoroughly soak the ground, and wash the soil down the slopes. Under these circumstances the topsoil, generally superficial, dries up rapidly; the trees are slow in growth, misshapen in form; on the other hand the timber is thoroughly lignified, and though it is unsuited for carpenters' work, it is in great demand for building purposes when its shape allows of its being so used.

On a *western* aspect the sun shines obliquely, but during the hottest hours of the day; the temperature is high, and the light fairly strong; the soil retains moisture with difficulty. The winds have the same character as on a southern aspect, and here, too, we find timber of slow growth, ill-shapen form, possessing the same good qualities and the same defects.

On these two aspects, the vegetation is early, and the young shoots of the season often fall victims to spring frosts.

Mountainous countries, especially deep moist valleys, are always exposed to the danger of frost, because the atmosphere is laden with watery vapour,

and this is condensed into fog or hoar-frost as soon as the sun goes down. The trees are not safe against this danger until they have outgrown the usual height of the fogs, *i.e.*, six to twelve feet.

The peculiar characters of each aspect may be modified by local conditions; in a valley an outjutting spur will change the original direction of the winds; on the Mediterranean, along the coast of Rousillon, the strongest winds come from the east, and bring moisture, &c. Again, elevation diminishes the effect of aspect, and towards the limit of forest vegetation, the difference between a northern and southern aspect is no longer sensible, growth is very slow, and the density of the wood small. Lastly, shelter on this or that side further changes the general effect of aspect.

CLASSIFICATION OF CLIMATES.—In order that we may have precise terms at our disposal, the general climate of France has been divided into the following :—

Hot climate; in which the cork, holm, and kermes oaks, and the stone and Aleppo pines are indigenous.

Mild climate; characterized by the cluster pine; the two large oaks bear seed in this climate almost every year.

Temperate climate; the two large oaks, the hornbeam and the beech are here very common; but acorns and beechnuts fall only every four, six, or even eight years.

Cold climate; here the beech with the silver fir and the Scotch pine constitute the large bulk of the forest.

Very cold climate; here among broad-leaved trees we only meet with the birches, mountain ash, service tree, &c., and it is the natural home of the spruce fir, and above all of the larch, and the Cembran and dwarf pines.

SOILS.—The function of the soil with regard to plants is twofold; it affords them a solid base, and it aids in their nutrition. Forest trees, however, require very little inorganic matter immediately assimilable, and what is more important, the greater bulk of these principles, taken up every year by the trees, is returned to the soil in their leaves and fruit; it may therefore be asserted that as regards forests the physical properties of a soil are far more important than its chemical composition.

The chief physical properties of soil are *depth*, *hygroscopicity*, *compactness*, and *colour*. It is the first two that chiefly affect forest growth; in a deep hygroscopic soil the trees make rapid growth and attain a considerable height; the latter feature is characteristic, and allows us to infer with certainty the depth or shallowness of a soil. The hygroscopicity of a soil, which is in direct proportion to its compactness, is the facility with which it absorbs a greater or less amount of water, and retains it with more or less force. On the compactness of a soil depends the greater or less ease with which it is penetrated by the roots of plants. The colour of a soil favours or diminishes its aptitude to absorb heat. The best forest soil is one which, besides being deep, is moderately stiff and fairly hygroscopic.

The mineral composition of the topsoil consider-

ably affects its physical properties. All soils are composed of argillaceous, calcareous or silicious elements, either pure or mixed in greatly varying proportions, together with a certain quantity of substances capable of assimilation by plants. If, then, we study the physical properties of each of these three elements separately, it will be easy to ascertain those of the soil in which any one of them may happen to preponderate; similarly we can deduce the properties of soils intermediate in character.

Clay is exceedingly stiff; it absorbs water slowly, but in great quantity, and a very sticky paste is thus formed; when a clay soil is saturated, water is no longer absorbed but has to remain on the surface. It retains water a long time, and on drying up shrinks considerably and becomes deeply cracked. A pure clay soil is unsuited to vegetation, because roots do not easily penetrate it; nor, when it is saturated with water, do they find enough air; also because they are torn asunder and wither up when the soil cracks in dry weather. Moreover, clay contains no nutritive elements.

Limestone, reduced to an earthy state, yields a very light soil which rapidly absorbs a large quantity of water forming with it a light-coloured mud. It loses this water with equal facility, and becomes a fine dust. Though yielding lime salts, it is unsuited to vegetation, because it is either too wet or too dry, and does not afford a sufficiently solid base for large trees. Limestone presents yet another danger; if caught by frost when in the state of mud, it swells and lifts up with it the young plants; when a thaw

sets in, the earthy particles sink down and leave the roots bare, which then wither up and die.

Sand is found in a granular state, and forms soils which vary considerably according to the size of the grains. When the sand is very fine, an almost impalpable powder, it has the same properties as clay, compactness and hygroscopicity being proportional to the fineness of the component particles. But usually, the grains of sand are of sufficient size to form a light soil that allows water to permeate to a great depth, and gives it up again with a remarkable facility.

Sandy soils then vary very much as to their physical properties; better suited to vegetation, when fine, even though they be pure, than clay and limestone, they are nevertheless poor soils, incapable of furnishing plants with any nourishment.

Although clay, limestone, and sand cannot individually form a fertile soil, yet when mixed they yield a rich and excellent soil, because the lime it contains is a source of nourishment, and its physical properties are not exaggerated, and therefore injurious, as is the case with any one of the three soils in its pure state.

Whatever be the mineral components of the soil, vegetable mould is sufficient to make it of good quality. For it corrects the excessive stiffness of clay, and the lightness of sand and lime; it absorbs and retains as much as twice its weight of water, without allowing it to filter through; it gives back the water more easily than clay, but more slowly than sand and lime; lastly, by a gradual deposit of carbonaceous matter which is not absorbed, it

renders the colour of every soil black. Moreover, mould yields in abundance elements of nutrition that are immediately assimilable.

CLASSIFICATION OF SOILS.—As regards the quantity of water they contain, soils may be divided as follows :—

Marshy. Those soils which are permanently covered by stagnant water ; they are quite unsuitable for forest vegetation.

Aquatic. Those that are constantly saturated; where water appears under the pressure of the foot but is enabled to drain away. In these soils we find the pubescent birch, the mountain pine, the elm, ash, willows, &c.

Damp. Soils in which water no longer appears under the pressure of the foot, but which never dry up at the surface in any season. They are the home of the peduncled oak, the alder, ash, elm, spruce fir, &c.

Moist. Those which dry up at the surface but not to a greater depth than six inches ; these soils suit almost every forest tree.

Dry. These soils dry up to a greater depth ; here we find the common birch, the Scotch pine, the cluster pine, the Austrian and Aleppo pines, &c.

According to their compactness, soils are either *stiff* or *light*, the former being principally composed of clay or impalpable grains of sand, the latter formed of limestone, or sand more or less gritty; on account of the water they contain, the first are termed *cold* soils ; the second, for a contrary reason, are designated *warm* soils.

A further distinction is made, according to their composition, between *rich* soils, which contain a large proportion of vegetable mould, and *poor* soils, containing little or none.

Marl is an intimate mixture of lime and clay; when exposed to the air it crumbles, and according as the clay or lime predominates, it is said to be argillaceous or calcareous, forming in the former case a stiff soil, in the latter case a light soil. Marl is a first rate soil, nutritive in itself, and highly suitable to every kind of cultivation.

Rich sand is a mixture of sand and clay; when vegetable mould is added to it, it constitutes the best soil for the growth of forest trees.

FOREST TREES.—The botanical description of forest trees belongs to the department of natural history, and will therefore find no place in this manual.

But before giving the treatment of the more important among them, we shall mention the climate and soil that suit them best, their habitat in plains or in mountainous regions, their manner of growth, qualities and uses, the requirements of the young plants, in a word, all that is capable of affecting cultural operations. It will suffice to give heret he characteristic features of the two grand divisions, broad-leaved trees and conifers.

The *broad-leaved trees* have annual leaves, with the exception of a few southern species; the cork, western holm, and kermes oaks, &c.; the leaves have a well-developed blade, and there is a bud at the axil of each. The result is an irregular ramification. Their wood is always formed of vessels, fibres and

medullary rays; they all possess, though in different degrees, the faculty of reproduction by shoots or suckers.

The *conifers* have persistent leaves, except the larch, which sheds them every year; the leaves are linear, and resemble needles; generally, it is at the axil of those only which surround the growing point that buds, capable of developing into branches, are found; thus the ramification is regular. The wood of conifers is composed exclusively of fibres and medullary rays; vessels are completely absent. The wood contains resinous juices. The trees, at least those of Europe, do not throw up shoots from the stool.

EXPLOITABLE TIMBER.—As we have said before, a forest is exploitable when it has attained its maximum of utility for its proprietor. This maximum of utility may be considered from two principal points of view: firstly, the greatest usefulness of the timber itself, and secondly, the greatest profit that can be derived from the forest considered as an investment.

Speaking generally, as long as the wood remains sound, the larger a tree is, the more useful is the produce that it yields. For in this case, besides being suited for a greater variety of purposes, there is less waste in working it up. Hence, the maximum usefulness of timber coincides with the age of maturity, that is to say, the age beyond which the timber, if unfelled, would run the risk of becoming unsound.

To fell the trees of a forest one by one as they

reach the age of maturity, or else to grow uniform crops, in order to fell them as soon as the mass of component trees attains this age, is evidently to work in the highest interests of the supply of the public at large; in other words, in the interests of the State which is the personification of the general community. But for this purpose, it is necessary to let the trees attain a great age, *i.e.*, to apply long rotations. Hence arises, as a rule, the necessity of growing high forest, for this is the only means by which the growth of vigorous and abundant stool-shoots can be effectually prevented; at the end of a long rotation no shoots from the stool would be produced.

Now high forest worked on a long rotation entails as a consequence the accumulation of a considerable amount of capital, the increase of which is out of all proportion to the increase of revenue which may be derived from it. In the case we are considering (that of forests) the ratio between the income and the capital employed to yield it, *i.e.*, the rate of investment, goes on steadily diminishing as soon as the forest has attained a certain age, and that not very far advanced. It is for this reason that the State and proprietors who are so to say imperishable, such as Communes and public institutions, are the only bodies that are able to produce the most useful timber.

As for the State, it is in the first place its imperative duty to grow the most useful timber because, as the representative of society at large, it is obliged to produce that which the public cannot

do without, and which private proprietors are not in a position to produce. This is indeed the chief reason why forests should be in the possession of the State. It is, moreover, to the advantage of the State that this should be so, for the consequent expansion of trade and the benefit to the public weal necessarily contribute to swell the receipts of the treasury. In the last place, from its being imperishable, the State is formed of an unbroken series of successive generations, each of which is an usufructuary of the State domains, without any one of them having the right to dispose of the capital which the latter represent. Now, to place the State forests on such a footing that they shall yield the scarcest and most useful products is evidently to make them return the highest revenue, leaving out of consideration the ratio between the income and the capital producing it.

This last consideration equally concerns all other imperishable proprietors, such as Communes, public bodies, &c.; but the general interests of the country do not affect them to the same extent as the State. This amounts to saying that it is their duty to preserve intact all forests they may possess which already yield the most useful products, but that they are not obliged to bring them into this state if the interests of the present generation would suffer too much thereby.

With respect to private, and therefore perishable, proprietors, forests stand to them in the same position as any other property; they represent so much capital invested, which they have at their complete

disposal, which they can sell, exchange or employ for any purpose whatsoever. They have no concern with the interests of the general public. Their object is to derive from whatever forests they may possess the highest returns consistent with the percentage of profits they expect to obtain. Thus they are driven to choose short rotations, in order to guard against the accumulation of a large capital in the shape of standing timber. Besides, their character is essentially speculative, and is thus opposed to the realization of profits at far distant dates. Hence, when the kind of tree admits of it, private owners exploit their forests at an age when stool-shoots are still produced with vigour and in abundance; *i.e.*, they grow coppice.

The first of these two kinds of exploitability which depends on the most useful produce and applies to imperishable proprietors, is termed *economic exploitability;* the second, which depends on the highest profits, and applies to private proprietors, is termed *commercial exploitability*. Besides these, there is still another, which concerns both classes of proprietor. This we term *physical exploitability*. Its object is to fell trees one by one as they die or enter into full decay. Here we neglect altogether the quality of the timber produced, as well as the money returns; we take into consideration nothing but the utility to be derived from the presence of standing timber, viz., either ornament or protection and shelter.

In order to realize the object of this or that exploitability, the forester has to adopt long or short rotations, and to apply the system of high forest or

that of coppice, either of which comprises several methods of treatment.

ANNUAL YIELD.—By the term *annual yield* we mean the quantity of produce that can be taken out of a forest annually on the condition that this quantity can be maintained at a constant figure. In order to realize it, we may take area as our basis, and cut over an equal area every year. But this takes for granted that throughout the whole extent of the forest, equal areas of the same age will yield equal quantities of produce. When the forest is rather large, it seldom happens that this is the case. Under these circumstances, therefore, we may divide the forest into a certain number of parts, each homogeneous in itself as regards productiveness; we can then treat these areas as so many working circles, in each of which we may base our annual yield *on area*, and express it in *acres*.

There are other occasions when the working circles are sufficiently homogeneous to admit of the above system, but the nature of the various cuttings carried on is such that they cannot be effectively performed by removing equal quantities of produce from equal areas. This case occurs in the regeneration cuttings of high forests. The annual yield is then based *on volume*, and is expressed *in cubic feet*. To determine the amount, all the trees in the block to be regenerated are counted and measured, and the cubic content thus obtained is divided by the number of years in the period. The quotient represents the number of cubic feet to be cut each year, and this amount is obtained from areas that vary every

year according to the cultural requirements on each occasion.

Again there are cases, as for instance in high forests worked on the selection system (see *infra*) when the exact calculation of the annual yield is of less importance than the object with which the selection system is adopted in any particular case. Here it is considered sufficient to cut over very nearly equal areas every year, removing a fixed number of trees per acre. In this method, therefore, our annual yield is expressed in *the number of trees*. If the forest has been divided into a convenient number of working circles, large fluctuations in the yield from one year to another need not be feared, and the forest is gradually brought into the most favourable condition for the proprietor.

PART II.

HIGH FOREST.

INTRODUCTORY REMARKS.—In growing high forest the object in view is generally to produce large timber, and to obtain natural reproduction by seed as a direct consequence of the cultural operations.

We recognise three principal methods of treating high forest.

1. The *selection method*, which, more than any other method, resembles the action of nature, and consists in cutting over rather extensive areas every

year, and in felling the trees one by one, or in small groups, here and there, as they become exploitable or begin to decay. This method was mostly employed in mountainous country, and especially in coniferous forests.

2. The method known as "*tire et aire*," which became generally adopted in France under the terms of the Royal Statute of 1669. In this method equal areas of forest were cut over successively in the order in which they followed each other on the ground, a fixed number of trees were reserved per acre, and the young crops that came up were left to themselves and grew on untouched for the whole length of the rotation adopted.

3. The *method of thinnings*, which is intended to obviate the defects of the two previous methods, and is founded directly on certain facts in nature. These facts relate to the conditions under which seeds germinate, to the requirements of the young plants during the first few years of their existence, and also to the phenomena which are observed in the growth and development of homogeneous crops left to themselves.

It would perhaps be more logical to study these three methods of treatment in the order in which they have been given above, but the importance of the method of thinnings claims for it the first place in this manual.

CHAPTER I.

METHOD OF THINNINGS.

NATURAL PHENOMENA ON WHICH THE METHOD IS FOUNDED.—1st. In order that a seed may germinate, air and a certain quantity of heat and moisture must be present. These three elements acting simultaneously are necessary and sufficient. Light is useful, but it is not absolutely necessary, and the heat that accompanies it, if too strong, as is often the case, may cause the seed to dry up, and thus prevent germination.

Nor again is the presence of soil essential to germination, though it favours it in so far as it distributes to the seeds in suitable proportions the elements of which they stand in need. But for this purpose the soil must be sufficiently free, and rich enough to provide nourishment for the plants immediately after germination.

As long as the soil is not well protected by the young plants, and their rootlets are small and have not penetrated deeper than the topsoil, which may dry up, the young plants require shelter from the heat. Later on they require complete exposure to the action of sunlight, and they should be gradually brought under its influence.

If to these facts, which are a matter of observation, we add the necessity of obtaining a thorough re-stocking of the forest, we deduce the following conditions, bearing upon natural reproduction and growth during the early years :—

A free and rich soil.

A complete natural sowing.

Shelter to the young plants for the first few years.

Their gradual exposure to meteorological influences.

2ndly. In proportion as the young trees grow up, their crowns require more room in the air, their roots more space in the soil. It follows then that a certain number amongst them must disappear. This may be observed in any completely stocked forest, the weaker plants succumb to the stronger, and die off one by one, until only a certain number of trees remain that are capable of living and doing well on a given area.

At the outset, this struggle between the various individuals does not last long enough to diminish the vigour of the more promising trees, or to injure the quality of their timber. It has, on the contrary, a useful effect, viz., that of cleaning the boles of their lower branches. But later on, when each tree has acquired a certain size, the weaker take a long time in dying off, and hinder the regular development of their neighbours. From this moment the struggle is injurious, and it becomes imperative to step in and shorten its duration.

Though, generally speaking, this struggle for life is advantageous to young stock, there are circumstances in which it may become dangerous. Such is the case when softwoods or brushwood, of more rapid growth than hard-wood trees, have crept into the forest, or else when the crop is composed of several valuable species, which it is important to keep growing together, and one of them grows up faster than the rest, and threatens to take possession of the

ground. If the forester does not step in at this crisis, the overtopped plants begin to wither away, and ultimately disappear altogether.

How the Method of Thinnings accords with these Phenomena.—To meet these two classes of phenomena, as well as to assist and to turn to account the action of nature, the method we are now discussing brings to its aid two kinds of cuttings, *Regeneration* cuttings and *Improvement* cuttings. The former are three in number, and they are termed respectively the *primary*, *secondary*, and *final* cuttings; the latter consist of *cleanings* and *thinnings*.

Regeneration Cuttings.—Reproduction by seed must only be looked for in those parts of the forest which have arrived at maturity. Strictly speaking, no doubt, a high forest may be regenerated as soon as the trees are fertile. But besides the fact that the timber at this moment is far from being really useful, the crop of seedlings produced at that period is seldom either complete or under favourable conditions of future growth. Nature does not act thus; a few seedlings may perhaps make their appearance under middle-aged timber; but it is only under old and lofty forest, which has already begun to admit a little sunlight, that young plants with some chance of living are found in any numbers. Besides, in all State or communal forests the interest of the proprietors is to produce the most useful material, *i.e.*, large timber. From losing sight of this fact many mistakes have been made; and people have even gone to the extent of denying the excellence of the method of thinnings.

PRIMARY CUTTINGS.—The primary cutting ought to realize the first three conditions mentioned above viz., the maintenance of a free and rich soil, the certainty of a complete sowing, and shelter to the young plants during their infancy.

It is under trees forming together a continuous leaf-canopy that the richest and freest soil is to be found; and it is the same kind of crop, when the trees that compose it are old but not verging into decay, that produces the best and greatest quantity of seed. But though the seeds germinate, it may happen, on the other hand, that the young plants will not live under this leaf-canopy for want of sufficient light; nay, if the parent tree possesses a very dense foliage, it is quite possible that there will not be enough heat for even germination to take place, and the seed has fallen uselessly on the ground. We are thus compelled to open out the leaf-canopy here and there on making the primary cutting. The extent to which the leaf-canopy should be thus interrupted must depend on the state of the soil, climatic conditions, and the constitution of the young seedlings (hardy or delicate), and no hard and fast rule can be laid down on the subject. We may distinguish, however, two methods of making the-primary cutting, and they are termed respectively the *open* and the *close* cutting.

A primary cutting is said to be *close* if the side branches of the reserves touch each other when swayed about by the wind. This definition is of the greatest importance, and in practice must be carried out *to the letter* whenever the necessity of such a cutting is clearly indicated by natural facts.

In the *open* cutting the intervals between the crowns may vary from seven to twenty feet.

The close cutting is the one which has most frequently to be employed. It is absolutely required in each of the following cases: when the seed is heavy and cannot be carried away far from the foot of the parent tree; when the constitution of the young plant is delicate; when the soil is liable to become choked with luxuriant grass, or to be dried up; when the operation is performed on the edge of the forest, or in localities exposed to the wind. For under these various circumstances we run the risk of an incomplete sowing of the ground, or the non-germination of the seed, or the dying off of the young plants for want of shelter, or the blowing down of the reserves either before they have sown the ground or before the young seedlings can do without shelter.

It is only when all the opposite conditions are found together, that the primary cutting can be made more or less open. In other words, the close cutting is the rule, the open one the exception.

When choosing the reserves, we must evidently select vigorous trees which have a lofty bole and a wide-spreading crown. It is far more important to secure an equal distribution of foliage than a regular arrangement of stems; and this should be our chief object. A close cutting that has been judiciously made should allow the sunlight to reach the ground not in large patches, but sifted as it were between the leaves as through a sieve.

The object in selecting reserves with a lofty bole

is to mitigate the action of cover, and to allow heat and rain to reach the ground in sufficient quantity. This length of bole is so important that it is frequently sufficient in itself to ensure the sowing of the ground. It is the aspect presented by old high forest that has grown up in close leaf-canopy. It is on this account quite lawful to increase the length of bole artificially by pruning even living branches, whenever the operation is performed on thick foliaged trees or on oaks which are to fall, at the latest, in the final cutting. There is yet another case in which it is essential to increase the height of cover artificially, viz., when the leaf-canopy is formed by a small number of trees which are thickly clothed with branches from their very base. Under such trees no seedlings spring up ; but once cut away the lower branches, and in the next year of seedfall numbers of young plants put in an appearance and thrive.

Besides selecting reserves with a lofty bole and artificially raising the cover by pruning, the soil must at the same time be carefully cleared of all brushwood and small shrubs with which it may happen to be overgrown. This precaution is of the utmost necessity, both to prevent the seed rotting in the winter, and also to ensure at the right moment the necessary amount of heat for its germination. The very existence indeed of the young plants also requires it; for they would rapidly disappear with such low cover just over their heads.

SECONDARY CUTTING.—As soon as the young plants have reached a certain age and the crop of

seedlings is complete, the time will have come to give them more light. This is effected by the secondary cutting.

But before proceeding any further, we must be quite agreed as to what we mean by a complete crop of seedlings. Strictly speaking, it is one which entirely covers the ground. But although such a result would always be desirable, it is seldom attained in one single year. The only case in which we may insist on it is where we have to deal with young plants of delicate constitution which can live on under cover from one year of seed to another. But in the case of hardy trees, while we are thus waiting for another fall of seed, we run the risk of seeing the young plants die off one by one under the cover, and having the crop always incomplete. In this case we must generally be content with a partial sowing, provided that the young plants are well distributed, and are in sufficiently strong numbers to close over the ground by the time they have reached the thicket stage, say in ten years.

The general procedure is to mark for felling the trees that overshadow the most completely stocked and vigorous patches of seedlings, and to leave untouched every spot where there are no young plants. Much judgment is required in this operation; while increasing the supply of light we mustguard against the drying up of the soil, which the seedlings cannot as yet protect by themselves.

Thus, in the majority of instances, we are obliged to extend the secondary cutting over several operations, a practice that is necessary in the case of

delicate trees, and always advisable in localities exposed to frost. Another reason for this measure is not to encumber the ground with too much produce at a time, and thus to lessen the damage done to the young plants by the timber operations.

If the primary cutting was made close and several years elapse without a fall of seed, the crowns of the trees may again meet over head and render it necessary to re-establish the original state. We cannot call this a secondary cutting, but rather a fresh primary cutting. Similarly if, after an open primary cutting, the soil becomes covered with brushwood and scrub, before seed falls, it will be necessary to clear all this undergrowth away, when one can foretell a year of seed.

FINAL CUTTING.—At length, when there is no longer any fear of frost or heat injuring the crop of seedlings, we may proceed to make the final cutting. The proper time to do this is when the young plants cover the soil everywhere, and have reached the thicket stage.

The final cutting consists in taking down the reserves left after the secondary cuttings. As far as regards the regeneration, it ought to be complete; and though some spots may not yet be sown, still the trees standing there should be cut down, and the places artificially filled up. The latter step will be unnecessary unless these blanks are too large to be rapidly covered over by the growth of the neighbouring crowns; to undertake to re-stock all the empty places, however small, would be at once useless and expensive. In the same way it would be no good

waiting for the natural re-stocking of these spots, because the soil must necessarily have deteriorated under the exposure, and will be no longer in a fit state to receive seed.

But although the young plants can henceforth do without shelter, it may be advantageous to leave a certain number of reserves standing, either to let them attain exceptionally large dimensions, or because they have not yet reached their most useful size. This is especially the case with the oak, for large pieces of which there is such a great demand, while their supply is diminishing every day.

The trees thus preserved must be carefully cleaned of all their *epicormic* branches.* It is because this has not been done that many oaks, left as reserves, have become stag-headed and have had to be cut down prematurely. This has led some people to think it impossible to preserve them, in spite of the incontestable proof to the contrary offered by old reserves which are scattered about in existing high forests. They evidently had to pass through the same ordeal of isolation which will in our case be lessened in intensity and shortened in duration to a remarkable degree by seasonable pruning.

We should never be in too much of a hurry to make the final cutting, because in the first place, the shelter afforded by reserves left standing here and there is the only sure means of protecting the young plants from the effects of late spring frosts in exposed localities; secondly, because until the

* The side branches which develop on the bole as soon as the tree is isolated; from ἐπί, on, and κορμὸς, stem of a tree.

thicket is thoroughly established the soil is not sufficiently covered and is apt to deteriorate; and lastly, because the amount of timber produced is increased by the further development of the reserves, which are too scattered and too high to cause any material damage to the young plants by the action of their cover.

It may be safely said that an interval of twenty to twenty-five years between the primary and final cutting is an average time for the complete regeneration of a forest; that there is always much to gain by proceeding with caution and prudence, and much to lose by trying to go too fast. In fact, one must take into account the years of seed over which one has no control and remember that germination, as well the as maintenance of the young seedlings, is exposed to many accidents which it is often impossible to foresee or to prevent. It has been often said that by giving up such a long time to regeneration, a clear loss in the yield was bound to result, and that it was more advantageous and more economical to have recourse to artificial methods of re-stocking. This is an error against which one cannot speak too strongly; artificial re-stocking always involves an outlay that cannot be put down at less than 30s. an acre, and this put out at interest would amount to a good sum at the end of a long rotation. Letting alone the fact that natural sowing costs nothing, we may say that there is no loss in the yield, because each reserve left after the primary cutting grows all the faster from having more space to develope in, and this extra production is the more useful, as it is obtained chiefly by an increase of diameter.

YIELD OF THESE CUTTINGS.—The secondary and final cuttings are made so as to favour the seedlings already on the ground; in consequence they are made at unequal intervals of time, and without any attempt at obtaining equal quantities of timber from equal areas; moreover the regeneration cuttings give the largest out-turn of the most useful material; hence their annual yield should be based on volume, and this will ensure a steady yield and the proper carrying out of the cuttings.

IMPROVEMENT CUTTINGS.—*Cleanings.* Take as many precautions as we may in carrying out the regeneration cuttings, it almost always happens, especially on rich soils and in temperate climates, that species with a light seed take possession of the ground, notably among these are soft-wooded trees, such as poplars, alders, willows and limes. They are generally rapid growers, and are not long in catching up and overtopping trees of more valuable kinds. At the outset their presence is no doubt useful because they promote the early formation of the leaf-canopy, but they become dangerous as soon as they attain the height of the hard-woods, and when they have once passed this height, they must be gradually removed, for when their foliage is in close contact with that of the more valuable trees, and just above it, the latter would soon begin to languish and might ultimately disappear altogether. A similar result often occurs in a mixture of two or more valuable kinds, one of which springs up more rapidly than the others during the first few years.

The operation which thus consists in removing

the higher trees which threaten the existence of smaller but more valuable kinds, is termed a cleaning.

To effect the object we have in view, the cleaning must evidently be commenced as soon as the evil shews itself, and sometimes during the process of regeneration itself. As a rule, however, there is seldom occasion to do it until after the final cutting, or at the earliest, simultaneously with it.

In carrying out this operation, great care must be taken not to destroy the leaf-canopy, firstly, because the soil can never be too well covered, and secondly, because if stems that are quite young are isolated, they are apt to bend and even to break under the weight of snow, hoar-frost, or their own leaves. If then there are too many plants to take away at once, they must be extracted by degrees. Moreover, the process which gives the best results is simply to bend them down instead of cutting them back at the roots, by this method an injurious cover is done away with, and at the same time a thick growth is maintained down below.

It is almost needless to remark that where nothing but soft-woods exist it is far better to preserve them than to fell them and thus to create a blank. They protect the soil if they do no more, and later on seedlings of more valuable trees will put in an appearance under their shelter, and these may be uncovered at the right moment.

It is but seldom that one single cleaning suffices to ensure the maintenance of the hard-wood rees, or to effect a proper admixture of the best kinds. It

has thus to be repeated several times until the object in view is attained.

Along with these rapidly growing and inferior trees it is indispensable also to get rid of clumps of shoots which may appear on some of the larger stools.

These shoots, which seldom hold out any promise in themselves, have at first a rapid growth, spread out wide, and destroy all the seedlings around them only to leave gaps in their place later on.

In making cleanings, the mistake has often been committed of removing at a single operation all soft-wooded trees, and birches. This procedure is too sweeping in its action. The birch and aspen are in great demand for certain purposes; the cover of solitary trees of these two kinds is too slight to do any real damage, and their wholesale extraction considerably reduces the money value of young crops.

THINNINGS.—Thinnings now step in and shorten the duration of the struggle between the individual trees of the crop. At first they are still in the nature of cleanings, inasmuch as they complete what the latter began, *i.e.*, the maintenance of the valuable kinds; afterwards their principal object is constantly to improve the growth of the more promising trees. We are thus led to distinguish the *first thinnings* from thinnings properly so called, which are made periodically, and for this reason are termed *periodical thinnings*.

Since the only way to improve the growth of the crop is to favour the gradual development of the crowns by setting them free, we may define a thinning as an operation in which we open out the

forest at the height attained by the crowns of the more promising trees. Advantage will of course be taken to remove from among the suppressed trees those which cannot survive until the next thinning, but this merely constitutes a simple utilization of produce and has nothing in common with the operation of thinning *as a thinning*, because it contributes nothing towards the improved growth of the forest, nor ought it to be undertaken at all unless the value of the wood obtained thereby at least covers the cost of exploitation.

A thinning is said to be *moderate* when the crop is opened out only to a moderate extent: it is *severe* when the crop is opened out more widely, without however going so far as to break the continuity of the leaf-canopy.

For whatever be the nature of the thinning, the leaf canopy must always be preserved. The reasons for this are simple, and depend on the age of the forest. In the first place, when the crop has reached the stage of low poles, the struggle for existence is only just beginning to be injurious; the full height of bole is far from being attained, and if the crowns are now isolated, the lengthening of the bole by natural pruning is stopped; even when the leaf-canopy closes up again overhead, the lower branches, having had time to attain a strong development, leave behind them on falling off large knots which depreciate the value of the timber; the trees having as yet a small girth in comparison to their height are liable to bend down and grow crooked; the ground is incompletely protected and becomes hard and

caked; the dead leaves are blown away and this essential covering to the soil, which must be kept free and rich, is hence lost.

In the second place when we destroy the leaf-canopy in a crop which consists of high poles, all the above disadvantages are incurred and, in addition, owing to the greater height of the trees, the wind may commit serious havoc; in the case of certain trees, especially the oak, the bole, already of a good height, will become covered with epicormic branches, which give rise to knots that depreciate the value of the timber, as it cannot then be employed in cooperage and other trades which require split wood; but the principal danger of these epicormic branches lies in the fact that they forcibly entail the decay of the crown, cause faults in the heart-wood resulting from dead branches, and sometimes occasion the death of the tree itself.

Lastly, as the forest grows old, the chief danger to be feared in isolating the crowns, is the creation of gaps by the wind, which go on ever getting larger and larger; the soil deteriorates more and more, and becomes unfitted for natural reproduction. If this fault has been committed, the most fortunate thing that can happen is for a crop of young seedlings to come up without delay. This will at least have the effect of protecting the ground and preserving its moisture and fertility.

Not only must the leaf-canopy never be interrupted in executing a thinning, but in direct opposition to what holds good for regeneration cuttings, the small shrub vegetation must be

carefully preserved; it prevents the layer of dried leaves from being blown away, keeps the soil moist, enriching it at the same time with its organic detritus, and so far from injuring—as some have maintained—the future trees of the forest by drawing nutritive elements from the soil at their expense, it ensures for them a vigour of growth which they would not otherwise have attained.

Between the level of this shrubby growth and that of trees with spare and contracted crowns which are cut away to set free the more promising trees, there are overtopped individuals of all heights. It is always advisable to preserve such trees, if they can survive till the next thinning operations come round. Besides the fact that they can in no way injure the taller trees, their preservation enables the forester to step in with a bold hand in setting free the crowns of species that rejoice in plenty of space and light.

In order that thinnings may have their full effect they must be repeated whenever the stock becomes too dense to admit of the normal development of the crown; in a word, we must follow step by step the progress of development. Now experience tells us that during the phase of upward growth they must be made more frequently than during the phase of diametral increase; but that for each period the requirements of growth are satisfied by their repetition at equal intervals of time. Generally speaking, we may say that up to seventy years thinnings should be made every ten years; after this age every fifteen or twenty years, according to species.

It only remains for us to find out at what age we

must begin to make the periodical thinnings. Before the timber has reached the stage of low poles, there is not enough difference between the various stems to enable us easily to distinguish those that are to be the trees of the future; we run the risk then of making mistakes if we begin to thin so early. Besides, up to this point the effect of the struggle has been distinctly useful, and it has already been pointed out that while making the last cleanings, a sort of partial thinning might be carried out if thought necessary. Under these circumstances it is more prudent to postpone the first periodical thinnings, until the forest has attained the stage of low poles, when the operation can be performed with a certainty of the result; this stage is generally attained towards the age of about forty years.

In order that the boles may be drawn up to a good height as well as to preserve the crop from accidents resulting from wind, heat, frost, &c., the forest can never be too full. The first thinnings then should be at the most, moderate, and at times there should be no hurry to begin them; and if the operation is performed on quick growing trees which naturally begin to crowd each other comparatively early, it will be sufficient to shorten the interval of time between two successive thinnings.

To prevent the wind from sweeping through under the forest and thus scattering the dead leaves, no trees must be felled for a certain width along the edges of the forest, except those that are in full decay; and to make this screen more effective, the low branches on the outside must not be lopped off.

From the first periodical thinning until the trees have attained their utmost height, the thinnings should be moderate for nearly every species, that is to say, while gradually allowing to each crown the necessary space for its regular development, the leaf-canopy must be opened out but slightly every time; even after this stage, while the growth is telling on the diameter, this will still hold good for the beech, the silver and spruce firs, &c., all of which species grow by nature thickly together and the timber of which has nothing to gain, and, in the case of conifers may even lose, in quality, by a rapid growth.

But in the case of trees whose quality and density are proportional to the rapidity of growth, especially the oak, it becomes advisable to open out the leaf-canopy freely, when the requisite height of bole has been attained. In this case it is necessary to thin heavily.

The last thinning, which precedes the regeneration cuttings, is generally severe, whatever be the kind of tree operated upon. But then it is no longer a simple improvement cutting; it is rather a real primary cutting. This is technically termed a *very close* primary cutting. Its effect is to open out the crop while still preserving the continuous leaf-canopy, and it differs from a severe thinning in requiring the removal of low shrubby growth from the soil. The advantages of working thus are all the greater, as regeneration is longer and harder to obtain according to local conditions.

In mixed crops, a thinning may always have the character of a cleaning. In a mixture of oak and

beech, for example, the latter frequently grows up faster than the former, and in order to liberate the crown of the oak without isolating it, it is better to fell the highest beech in the immediate vicinity, and to preserve those that are suppressed.

The beech will not be placed at much disadvantage by this proceeding; it is here only the companion tree, and besides can well bear the light cover of the oak.

As may be gathered from what precedes, a thinning is always a delicate operation and difficult of execution. It requires unflagging attention and real practical knowledge. Made at the right time and well carried out, thinnings are in every way advantageous; by gradually setting free the more promising trees, a healthier vegetation is promoted and a more thorough lignification of the wood ensured; although well stocked high forests do not yield as close-grained and as tough a timber as that obtained from isolated standards, nevertheless their timber is of medium quality suited for almost every purpose. Now it must not be forgotten that looking at all the timber worked up in France, manufactures use up a much larger quantity of wood than that required for building purposes, and they do not want tough-grained wood.

Thinnings too allow us to effect a proportionate distribution of trees in mixed crops according to our wants. As they are made periodically, we can always get rid of any one kind when it becomes dangerous or when it has attained its maximum of utility. In this manner we shall avoid rooting out

wholesale any particular species while the forest is yet young, an operation that is always a mistake, as each kind of tree is useful in its own special way.

By means of thinnings valuable produce is brought into the market which would otherwise have been entirely lost. This produce is generally equal in quantity to a fifth or a quarter, sometimes to a half of that yielded by the regeneration cuttings, and with some species, may equal the latter.

Lastly as thinnings deal principally with suppressed and sickly trees, they tend to prevent the propagation of wood-devouring insects, which attack such trees by choice, and sometimes threaten the destruction of certain kinds of trees, particularly the conifers.

But we cannot repeat too often that if these advantages accrue from a thinning carefully carried out, an injudicious thinning may compromise the future of the forest; much better would it have been in that case, not to have made one at all.

Now if we compare the relative importance of cleanings and thinnings, we shall see that the former are necessary, while the latter are only useful. For, in point of fact, cleanings ensure the very existence of the valuable trees, while thinnings merely improve their growth, and in consequence the quality and the usefulness of their timber.

CHAPTER II.

APPLICATION OF THE METHOD TO THE PRINCIPAL FOREST TREES.

I. TREATMENT OF HIGH OAK FOREST.

HABITAT.—When the oak is mentioned without further specification it always means either the British Oak (*Q. pedunculata*), or the Sessile-flowered Oak (*Q. sessiliflora*). These two trees inhabit mild and temperate climates, the former advancing further north, the other more towards the south, but their habitat is chiefly determined by the amount of moisture in the soil. Thus the former prefers very moist and even damp soils, containing a rather strong proportion of clay, the latter, free soils that are merely moist. The former is chiefly found in plains; the latter, though also found in plains, prefers hilly or low mountainous ground.

PECULIARITES OF GROWTH.—The seed of these two oaks is heavy, the cover light, and the young plant hardy, though it cannot stand spring frosts. Their roots take a vertical direction downwards and the taproot is very long in the early life of the plant. They do not produce suckers, but they throw up shoots from the stool up to an advanced age. Their growth, somewhat slow at the beginning, becomes rapid in good soil and the more the crown is developed, the greater density does the timber acquire. When an individual tree is isolated, or at some

distance from its neighbour, the bole covers itself with epicormic branches and becomes knotty, especially in the case of the peduncled oak.

Both are trees of great longevity, of great height, and capable of attaining immense girth. Their sapwood, the thickness of which is sometimes considerable, decays rapidly, and it is essential to cut it out from timber intended for any important use.

USES.—The oak is employed in large works by sea and by land, is almost the only material used as staves for wine and brandy casks, and sawn up, yields most valuable planking. The bark of young trees is in great demand for tanning purposes. Coppice shoots, standards, and high forest trees of medium age yield, when barked, a firewood of fairly good quality; but the wood of old oak trees flies to pieces in the fire, and burns badly in open grates. Oak charcoal is in demand for smelting mineral ores.

Although the quality of the wood yielded by these oaks may be as varied as the soils and climates in which they grow, still it may be said in a general way that the peduncled oak chiefly furnishes beams and large pieces for building purposes, while the wood of the sessile-flowered variety is more in demand for those industries which use sawn and split—in other words worked up—timber. The bark of the latter, too, is the more valuable.

ROTATION.—To meet these various demands, large trees are much the best, because for a given volume, the loss in working up is less; large oak alone can be profitably worked up into staves or sawn so as to show the silver grain. Thus wherever the trees can

be grown to seven or eight feet in girth without decay of the heartwood, they must be allowed to reach at least these dimensions before they are felled. To obtain such trees in high forest, it is necessary to adopt rotations of from 160 to 200 years according to the fertility of the soil in each case.

REGENERATION.—Pure oak is always harder to deal with than when it is associated with other species; the produce of a pure oak forest is of less general use; the wood is too soft; moreover it is very seldom that pure oak is found naturally over large tracts of country. Nevertheless as this state of things does sometimes occur, whether in the course of nature, or as the result of ill-advised operations, we must investigate the rules that are applicable both to the regeneration cuttings and to the improvement cuttings, only we will take the opportunity of pointing out the advantages of the association of oak with other trees, and will at the same time indicate the rules to follow in the latter case.

PRIMARY CUTTING.—Because the acorn is heavy, but chiefly because the soil must be kept moist and free from long grass and brushwood, the primary cutting must be made close. To ensure the preservation of the seed until the following spring, and to assist its germination, it is especially important to clear the ground of all brushwood, and to leave as reserves, trees with a lofty bole. If this latter condition cannot be realised, because the forest has been too thinly stocked in past time, it will be a judicious step to prune away the lower branches,

taking care only to operate thus on mature trees that would have to fall in any case after a few years. There will be no harm in doing this as the decay resulting from the wounds will not have time to sink deeper than the sap-wood.

SECONDARY CUTTING.—After acorns have fallen and a few young plants may be found on the square yard, we may consider the sowing complete, and it becomes necessary to give the young oak the light their hardy constitution requires; but at the same time the ground must not be uncovered too hastily. For this reason it is preferable to make at least two secondary cuttings; the first when the seedlings are two or three years old, the second a few years later.

FINAL CUTTING.—It is only when the young oaks, either by their own development or with the aid of associated species, have formed a thicket on the ground, that the final cutting can be safely made, It is even advisable to postpone it yet a little longer in wet and low localities exposed to spring frosts, which are felt even in mild climates. Hitherto this is the only effectual remedy that experience has taught us; the young crop, under the reserves as left by the secondary cutting, must have reached the usual height of the mists that accompany these frosts.

At the time of this final cutting, it is essential to preserve all oaks that are in a good state of growth and not yet mature in the true acceptation of the term. Their maintenance in a sound condition may be ensured by pruning the epicormic branches, as often as necessary, clean along the bole, either with

the bill-hook or with the pruning knife, but the use of climbing irons must be strictly prohibited, because if the wounds they inflict go as far as the sap-wood, decayed spots are certain to result. The trees thus temporarily preserved are intended to be felled as they mature or show signs of decay. Their reservation is fully justified by the great and increasing scarcity of large oak in France, and the enhanced utility of timber of large dimensions; and it thus becomes a matter of supreme necessity in State forests and one of the highest utility in communal forests. Whatever be the number of these reserves, and it is improbable that they will ever be too numerous, a long time must necessarily elapse before they become really injurious to the undergrowth. Besides this, the fact that they will be utilised much sooner than the underwood should secure them the first consideration, even if the latter does suffer in consequence here and there.

IMPROVEMENT CUTTINGS.—*Cleanings.*—At the time of the final cutting, sometimes even before, but in any case not long afterwards, brushwood and other species that may have crept in among the oak, begin to outgrow the latter and threaten their very existence. It now becomes imperative to protect the oak by means of cleanings. It is principally in rich and moist soils under a temperate climate, that the soft-woods spring up rapidly and in great abundance, and tend to expel the oak; the lime and the great sallow are by far the most dangerous. Immediately they outstrip the oak, no time must be lost in topping them, a method that is preferable to cutting them

back down to the ground, unless indeed they are only few and far between; the leaf-canopy is thus completely preserved down below, and natural pruning goes on among the small branches, which then fall off without leaving any appreciable knots on the bole.

It is often necessary to repeat the cleanings, especially if the first operation was judiciously and cautiously performed, but we must not postpone felling the soft-wood trees until they have attained a certain commercial value; it should never be forgotten that the operation is urgent, and that the more the oak stands in need of light, the faster will it wither away. In short, cleanings must be made *whenever* and *wherever* they are necessary, without giving a thought to the produce they may yield.

Among the trees of rapid growth which often invade a crop of oak seedlings, the birch claims our special attention. This tree has a very light cover, and its leaf-blades hang vertically; hence it does but little injury to the oak unless it forms a complete canopy above. Indeed it is often useful to the oak, if the final cutting was made too soon, by providing shelter against spring frosts. We must therefore remove the birch gradually, felling only a few at a time, and selling the produce either for faggot bands, or cask-hoops, or for any other purpose that may chance to occur. Moreover it should not be forgotten that there is a large demand for birch wood in certain industries, and that as far as the quality of the oak is concerned, its association with this tree is far preferable to pure oak. The preceding remarks often hold good for the aspen as well.

THINNINGS.—When the young crop, after successive cleanings, has reached the low pole stage, the time has come to begin periodical thinnings. It is evident that in the last cleaning operations, one may have been compelled to cut a few oak in places where they were too thick, but this is not a true thinning, and generally speaking, the unassisted action of nature would have sufficed to liberate in time those plants that are to form the trees of the future.

But this remark no longer holds good when the suppressed poles are too long in disappearing of themselves, since the free development of the crowns is an object that must constantly be kept in view. Nevertheless, seeing that the full height of the tree has yet to be attained, the growth of epicormic branches to be prevented, and the soil to be protected as completely as possible, the first periodical thinnings in a crop of pure oak must be moderate, that is to say, only those trees which are on the point of becoming suppressed should be removed, the operation as a consequence being repeated at shorter intervals.

It is only when the crop has reached the high pole stage, and not before, that we can begin to thin more severely; but here on the other hand all low shrubby growth should be carefully preserved, even plants of quite secondary importance. However we go to work, we cannot manage without danger to set free the crowns as much as they require, and the almost necessary consequence will be that the trees, though drawn up to a good height, it is true, will be thin out of all proportion and contain soft-grained wood.

Every endeavour should therefore be made to protect other kinds of trees that may come up spontaneously in the forest and even to introduce them artificially—the better kinds at least—as soon as the cover of the oak crop is sufficiently high. The beech and the hornbeam, according to soil and climate, are the trees most generally found in company with the oak, and whose association is most favourable to the latter; in very damp situations where they cannot follow the oak, their place is taken by the ash, alder, elm, &c.

The treatment of the oak associated with other trees will be discussed further on.

II.—TREATMENT OF HIGH BEECH FOREST.

HABITAT.—The beech is met with in the plains as well as in mountainous regions. It is found in abundance in localities enjoying a cold or temperate climate, grows less common as the climate becomes milder, and disappears altogether in hot climates. This is tantamount to saying that in the south of France it is confined to hilly ground above a certain elevation and on cool aspects; it is not particular as to the mineral nature of the soil, provided that it be free and fairly moist. It attains its finest growth on lime-stone and sandy soils.

PECULIARITIES OF GROWTH.—The seed of the beech is heavy, its cover exceedingly dense, and its young plant very delicate, being unable to withstand either spring frost or great heat. The root, inclined

to become long and deep at first, soon presents lateral ramifications, and at what is yet an early age, the roots all run along close to the surface of the ground. The beech sends up no suckers, and in some localities shoots up indifferently from the stool.

The rate of growth, rather slow at the start, is however a little bit quicker than that of the oak, but it is worthy of remark that under a complete canopy, though this be lofty, beech seedlings will cease growing when they are about three feet in height, and in this state they will live on for an indefinite period, still retaining the faculty of shooting up when the supply of light is increased; later on, oak and beech go ahead at about the same pace. The beech is a tree of great height, but is shorter lived than the oak, and does not attain as large a girth. The quality of its timber is not proportional to the rapidity of growth,* and the sapwood is similar to and may serve the same purposes as the heart-wood.

USES.—Beechwood warps easily, and decays

* For broad-leaved trees the general rule on this point is as follows:—In each annual ring of wood, the pores (vessels) are, first, either equally distributed; or, secondly, congregated nearly all together along the interior edge of each ring, and are wanting, or very small and scattered, towards the exterior edge.

In the latter case, the inner portion of each ring, which is formed in spring, and is hence termed "spring-wood," is light and porous, whereas the outer portion produced in autumn and called "autumn-wood," is composed of compact woody tissue. Now it is found that for the same conditions of soil and climate, the thickness of the porous or spring-wood is uniform, *i.e.*, remains constant, and any increased rapidity of growth tells only on the autumn wood. Hence in this case which includes such trees as the oak, ash, &c., the more rapid the growth, the greater the proportion of compact woody tissue the tree will contain, and the heavier will be its timber.

rapidly if it is alternately wet and dry. It is thus ill-adapted for building purposes, except for sub-aqueous constructions; but it forms a splendid manufacturing wood, and is much used in cabinet work, wheelwrightry, cooperage, and coach-building, and for packing cases, measures of capacity, and wooden shoes. It splits readily and evenly, while yet green, but it should only be used when thoroughly seasoned, as it shrinks and contracts in all directions.

Impregnated with sulphate of copper, it has been used for railway sleepers, but hitherto with an indifferent result, for it does not last any longer than unimpregnated oak. Benzine is now taking the place of sulphate of copper in the impregnation of beech.

Its firewood and charcoal are much valued. The fruit yields an edible oil.

ROTATION.—The different services to which the beech is put do not require it to be of great size, and as the sapwood is used, it is generally sufficient to obtain trees of six to seven feet in girth. So we may apply to this species, growing in High Forest, rotations of from 120 to 160 years.

REGENERATION.—The beech forms large forests by itself, but it is also frequently associated with oak, silver fir, maple, Scotch pine, &c. We must first of all then study it in its pure state, and afterwards enquire how the treatment should be modified when it is growing with other species.

PRIMARY CUTTING.—The very delicate nature of

The former case, with uniformly distributed pores, is obviously unaffected by slowness or rapidity of growth; it includes the beech, hornbeam, poplars, willows, &c.

the young plant is in itself valid reason enough to make this cutting close. The rules to follow are the same as those already indicated for the oak, only, since the cover of the beech is very thick, the boles of the reserve should be still higher; as before, the lower branches may be pruned off if necessary, the operation in this case entailing no risk of damage to the timber of the trunk.

In case a few years pass by, and no fall of beech-nut takes place, the leaf-canopy, which was but slightly interrupted by the close cutting, may fill up again, because in the case of the beech the side branches of the crown grow somewhat rapidly. If this should happen, it will be necessary to re-establish the conditions of the primary cutting.

SECONDARY CUTTING.—Young beech are capable of remaining a considerable time under a high cover before dying off; for this reason we may safely wait until the crop of seedlings is completed by successive years of seed, before proceeding to make the secondary cutting; indeed this course is necessary to keep the soil constantly protected. We know that the young plants require more light when, side branches having made their appearance, the stem begins to make decided upward growth, this happening towards the age of three or four years. In view of the delicate constitution of beech seedlings, we must act prudently, and make the secondary cutting by degrees, not in one single operation.

FINAL CUTTING.—At length, when the young thicket is thoroughly established, forms a perfect protection to the ground, and thus ensures the

maintenance of the soil in a moist state, the final cutting may be undertaken; this will remove all the reserves still left standing. There is indeed no object in leaving the beech to attain an exceptional size, and the superficial character of its roots would seldom allow it to withstand isolation.

The more the soil is liable to dry up, and the more the wind is to be feared owing to elevation or aspect, with so much the greater prudence must the regeneration of the beech be effected. In the vicinity of mountain ridges and passes and at the higher limit of vegetation, it may even become necessary to keep the forest constantly full, and to apply what is known as the selection method; but this will be treated of later on.

IMPROVEMENT CUTTINGS.—*Cleanings.*—Cleanings are much less urgent for the beech than for the oak, because it is better adapted to withstand the action of cover. Still they are always useful, and may even become necessary wherever maple and elder are numerous. The latter indeed is useless, and the beech might disappear if subjected for too long a period to the cover of the maple. Nevertheless, taking into consideration the various purposes for which the maple is used, it would be an error to get rid of it wholesale; on the contrary, a certain number must be preserved here and there to be removed later on in the thinnings when they have reached a useful size.

THINNINGS.—Like almost all trees possessing a thick cover, the beech grows well in a dense canopy. This circumstance, added to the fact that it is fre-

quently found in mountainous country, where it has to bear the weight of superincumbent snow and hoar frost, compels us to postpone the moment for thinning out the stock. The first periodical thinning then is not to be made until the crop has distinctly attained the size of low poles. At this stage the well marked difference in size of the suppressed trees will point them out as having to fall, and there will not be much risk of making any gross mistake. Until the trees have attained their full height, the thinnings should remain moderate. From this time forwards it will prove expedient to open out the stock rather more without ever going so far as to thin severely.

III.—TREATMENT OF HIGH FOREST OF OAK AND BEECH MIXED.

ADVANTAGES OF THE MIXTURE.—From the nature of the soil suitable to the beech, it is chiefly with the sessile-flowered oak that we find it naturally associated. Many are the advantages of this mixture.

(i.) The two trees require the same climatic conditions, and though the beech is not so long lived as the oak, it suffers no harm from having to wait until the latter is old enough to be exploitable.

(ii.) Their roots penetrate the soil in different directions, and this allows a greater number of trees to flourish on a given area without injury to each other.

(iii.) The cover of the beech is dense, and comes in as a corrective to the baneful influence exercised on the soil by the light cover of pure oak.

(iv.) The bole of the oak, protected by the shade of the beech, is not liable to become covered with epicormic branches.

(v.) The timber of the two trees serves different purposes and thus the wants of the market are more fully supplied.

(vi.) The yield of the first periodical thinnings becomes more valuable if the beech is numerous enough to allow the thinnings to tell on it more than on the oak.

(vii.) Lastly, a complete crop of seedlings is sooner obtained, because the years of seed do not always coincide for the two trees, and the proportion of oak need not be large in the young crop.

But, on the other hand, there are disadvantages arising from the fact that the beech is frequently a faster grower than the oak during the first few years, and that later on, when the two go ahead at about the same pace, the thinnings require great nicety of judgment for their execution. So the forester cannot be invited too earnestly to give his best attention to the treatment of these two trees associated, and carry out, whenever he can, connected series of observations relating thereto.

Our present knowledge on the subject appears to be summed up in the following rules.

ROTATION.—Whenever the proportion of oak in the mixture is appreciably large, one-tenth, for example, the rotation must be fixed so as to allow this tree to attain a girth of seven to eight feet, that is to say, at from one hundred and sixty to two hundred years; but if the oaks are simply scattered here and there,

and the conditions of soil and climate will not admit of a greater number in the future, a rotation may be chosen more nearly coinciding with that suitable to the beech, only care must be taken to leave the oak standing after the final cutting.

PRIMARY CUTTING.—As for either tree separately, so in the mixture of oak and beech, the primary cutting must be made close. The same precautions of cleaning the soil and artificially raising the cover must also be taken here. But it may be asked, in what relative proportions should the two species compose the reserve? Clearly no definite rule can be laid down on this head; however, it may be remarked that if it is advisable to have more seedlings of beech than of oak at the beginning, it is not necessary, on that account, to reserve more beech trees than oak; for this reason, that the beechnut falls further away from the parent tree than the acorn, and the young beech plants thrive well under the shelter of the oak, whereas oak seedlings die off under the thick cover of the beech. Now, it must not be forgotten that at first the oak grows slower than the beech, and that the state of matters is bad enough for the former, without making it still worse.

SECONDARY CUTTING.—The secondary cutting must not be undertaken before a crop of beech seedlings exists on the ground. The constitution of these seedlings is such that none will be obtained under a crop that has been much opened out; and provided that a few oak plants are found evenly distributed over the whole area, the proportion of

these must be considered sufficient. From this time forwards the growth of the oak is to be favoured as much as possible, taking care at the same time not to compromise the beech; to attain this object, a first secondary cutting must be made slightly more open than would be necessary for pure beech, and it should remove chiefly the beech reserves. Another secondary cutting must be made a few years later.

In case a fall of beechnut occurred before a fall of acorns, it would be advisable to plant out young oak under the stock as left by the primary cutting, putting them twelve to fifteen feet apart in each direction, and in regular lines. Otherwise, there would be the risk of seeing the beech push ahead rapidly after the secondary cutting, and remain in sole possession of the ground. If, on the other hand, a complete seeding of oak is obtained first, it must not be allowed to disappear; but care must be taken in the secondary cutting, which will then be made rather light, so as to ensure the maintenance of the oak, to leave standing a sufficient number of beech. We shall presently see how a well proportioned mixture may be secured.

FINAL CUTTING.—As soon as the seedlings have closed overhead and reached the thicket stage the final cutting is to be made. Every thriving oak, that is capable of flourishing in good condition for the next thirty years at least, must be left standing. All the precautions in the way of pruning off epicormic branches, previously mentioned, must be adopted in the case of these oak reserves.

IMPROVEMENT OPERATIONS.—*Cleanings.*—At the

time of the final cutting, or shortly afterwards, cleanings become necessary to set free the oak, whether these are self-sown or planted. These cleanings will get rid of the soft woods, inferior species which may have crept in, and especially those beech which threaten to overtop the oak. It may even happen that a few partial cleanings have to be made before the final cutting itself.

When there is a large majority of oak seedlings in the young crop, there must be no hesitation in sacrificing a few of them here and there, so as to secure a proportionate mixture in the future.

Cleanings may thus commence what thinnings will complete, *viz.*, the attainment of a satisfactory proportion between the two principal trees, and the assurance of their healthy vegetation.

THINNINGS.—We must never lose sight of the fact that the oak should always have its crown free if we want to obtain large sized and well lignified timber. This is often a source of serious difficulty in the treatment of mixed oak and beech, because the latter, even when its upward growth slackens, still pushes ahead at least as fast as the oak, whose bole has to be guaranteed against the formation of epicormic branches. Nevertheless if from the very beginning the thinnings are always carried out with a view to favouring the oak, excellent results may be obtained. To this end during the first thinnings, the forester will make it a point to fell the tallest and most vigorous beech among those which are in the immediate vicinity of oak, leaving untouched by preference those that are slightly overtopped. The

same object is to be aimed at in succeeding thinnings, and in the end we shall have high-boled oaks, with an amply developed crown and a trunk of considerable girth. Naturally the beech thus preserved will suffer to some extent, in spite of the light cover of the oak; but, thanks to its constitution, they will still manage to exist, and the future seed bearers will be found among those trees that have normally developed in the intervals between the oak.

It is perhaps as well to remark that in crops, which have already entered at least the high pole stage, the greater part of the evil has been already effected, and it becomes almost impossible to bring back the oak into favourable conditions of growth.

As regards the nature of the thinnings the general prescriptions laid down must be followed, that is to say, the first thinning must be made moderate except in the immediate neighbourhood of the oaks, whose crowns will be set quite free after the manner of a cleaning, and the succeeding thinnings, when the crop consists of high poles, will, while opening out the crop rather more freely, never be severe. For with these precautions the thinnings, which will be of a medium character over the whole crop generally. will have all the effect of a severe thinning for the oak. At the same time the soil will remain thoroughly protected and will constantly improve in quality.

IV.—TREATMENT OF HIGH FOREST OF OAK AND HORNBEAM MIXED.

ADVANTAGES OF THE MIXTURE.—The hornbeam is not of sufficient importance to be grown in high

forest for its own sake, but it becomes most useful when associated with the oak. It was formerly destroyed, as being no better than the soft woods, and this mistake was perpetuated for centuries, so now it is being protected or reintroduced in the very same localities where war to the knife was once waged against it. Like all the large trees, it should be utilised wherever it grows naturally, and not unfrequently indeed it has to play rather an important part.

Except as regards the market, the hornbeam considered as a companion for oak, offers the same advantages as the beech; it flourishes even in very moist soils, where the beech ceases to grow, and thus becomes the natural ally of the peduncled oak.

From a purely cultural point of view the hornbeam is superior to the beech, inasmuch as it always grows slower, and remains smaller than the oak, but its longevity barely exceeds a century and a half. Still that is no reason for excluding it from oak forests, and although it is chiefly a question of a far distant future we shall see further on that this difficulty is more apparent than real.

In a good many localities the oak is mixed sometimes either with the beech or hornbeam, at other times with both together. This latter condition is most advantageous as it guarantees a quicker and more complete regeneration, and facilitates the operation of thinning in the interests of the oak; it would thus be a great mistake to get rid of the hornbeam on the plea of its being less useful.

The hornbeam is not one of our loftiest trees, it is

found somewhat widely distributed in temperate regions, chiefly prefers clayey soils, but still does well in free soils that retain their moisture at a slight depth below the surface; it is met with in the plains as well as on hilly ground. While avoiding great heat, the hornbeam appears to require rather a strong light; it is capable of withstanding frost to a remarkable degree.

The hornbeam is a species that becomes fertile while still young and bears fruit nearly every year. Its seed, furnished with a leafy bract, is borne to a considerable distance by the wind, but it does not germinate until the second spring after its fall. The tree has a thick cover, and the young seedling though not injured by frost, is exceedingly sensitive of the drying up of the soil, owing to its roots being very short at that age; as the plant grows up, the roots are more apt to spread out laterally than to descend vertically, and do not go deeper than twenty inches. The hornbeam shoots up very freely from the stool up to an advanced age, and also throws up suckers.

This tree is always a slow grower, and, as we have already said, attains only a medium size. Its stem being more or less fluted, the wood cannot be used as timber, and all the more so, that it cannot withstand the alternations of the weather; but it is valued for wheelwrightry, and all parts of machinery exposed to friction; it is one of our best fuel woods, and it yields most excellent charcoal.

ROTATION.—This should always be chosen so as to obtain the most useful produce from the oak.

PRIMARY CUTTING.—To keep the soil in good con-

dition, the primary cutting must be made close, and it will be unnecessary to reserve a large proportion of hornbeam as its seed is borne away by the wind to long distances.

Under this close, or even very close cutting, if the soil is liable to be overgrown with tall grass, the oak alone will reproduce itself; or if hornbeam seedlings do come up it will generally be to disappear during the course of the same year.

SECONDARY CUTTING.—As soon then as there is a little oak everywhere, the secondary cutting must be undertaken; this will be the real primary cutting for the hornbeam. At this point it must be remembered that if the hornbeam requires a certain amount of light, it cannot withstand the drying up of the soil, and the invasion of grass; hence it is essential to make this cutting light, and to secure reserves with a high cover. Until the hornbeam seedlings have got well hold of the ground, *i.e.*, towards the age of six or seven years, it is necessary to be very cautious, indeed, it is often advisable to withhold one's hand altogether. This condition once realized, a second secondary cutting must be made, which will get rid of all the hornbeam reserves, and in case of need, a certain number of oak also.

FINAL CUTTING.—The final cutting will take place as before, when the young crop forms a complete thicket, promising oak trees being reserved to attain finer dimensions.

IMPROVEMENT CUTTINGS. — *Cleanings.* — Inferior species that may have crept in during the regeneration, must be got rid of by cleanings; but there is

no fear of seeing the oak overtopped by the hornbeam, except perhaps by stool shoots. On the other hand, we sometimes come across spots where the hornbeam is very rare, in the midst of a complete crop of oak seedlings. In such a case, we must save the hornbeam by removing a few oak.

THINNINGS.—The thinnings must follow the general rules, and must be of moderate strength. We have already seen that the hornbeam does not live so long as the oak; trees of the former species must be removed as they begin to die off. The leaf-canopy being thus gradually opened out, new hornbeam seedlings will make their appearance; they will go on growing as more and more light reaches them, and will form a constant protection to the boles of the oak. This is what occurs in nature, and it is a valuable hint with which to refute the systematic idea of a regular double regeneration of the hornbeam during one rotation of oak. For besides the difficulty of obtaining a new general seeding, there would always be a risk of the oak covering itself with epicormic branches, and going to decay during the whole time that must elapse before the new generation of hornbeam can rise up high enough to protect the boles of the oak. Besides this, a certain number of hornbeam will always survive for a whole rotation of oak, and will suffice to yield seed enough to keep up the mixture when the crop is fit for felling.

V.—TREATMENT OF HIGH FOREST OF BROAD-LEAVED SPECIES MIXED.

Forests are frequently met with in which ash,

elm, maple, birch, aspen, alder, and fruit trees are more or less abundantly scattered about amidst a crop of oak, hornbeam and beech. Although generally speaking, these species are of different degrees of longevity, this is no obstacle against their maintenance in the forest; on the contrary, there is an advantage in retaining a certain proportion of them on account of their special uses. However the *Ulmus diffusa* must be excluded; its wood is of very inferior quality, and its presence can only be justified where its extraction would leave a gap in the leaf-canopy.

ROTATION.—Whenever these forests contain a sufficient proportion of oak, the rotation must always be chosen to suit this species, keeping in mind its requirements and the uses to which it is put.

REGENERATION CUTTINGS.—The rules laid down for the trees mentioned in the preceding sections are entirely applicable here. When the young oak is sufficiently numerous and equally distributed over the ground, the complement of the seed crop must be made up with other kinds, always giving preference to those which are longest lived, notably the beech and the hornbeam; but it will suffice if there are a few everywhere, the chief thing being to have the thicket formed as early as possible. Of course the procedure must be such that the final cutting may find a reserve almost entirely composed of oak.

IMPROVEMENT CUTTINGS.—If the young crop contains all these species of different peculiarities of growth and degrees of longevity, it is very evident that cleanings must begin early, in order to ensure

the maintenance of the oak and to allow each of the associated species to assume its relative proportion in the mixture. For this purpose, it must be remembered that in old crops the elms, the ash and the maples never form leaf-canopy, but occur merely scattered about here and there. On this account too many are not to be reserved on the same spot. The sycamore maple especially has a rapid growth and a thick cover, while it does not attain a great age. In the thinnings, the proportioning between the various species must be continued, never losing sight of the oak, and the shorter lived trees must be felled as they acquire respectively a marketable size. It might be feared that in so doing none of the latter would be left at the moment of the ensuing regeneration, but these species generally have a light seed, which we know by experience is wafted to great distances. If there be only a few of them in the neighbouring pole crops, we are sure to obtain a sufficient number of seedlings during the whole period of regeneration.

VI.—SUMMARY OF THE TREATMENT OF HIGH OAK FOREST.

In recapitulation, the rules relating to the treatment of high oak forest may be summed up as follows :—

The oak should never be grown by itself, if we wish to obtain the most useful produce it can furnish.

Its regeneration should be obtained by self-sown seedlings and introducing it artificially should only be a complementary measure.

Whatever be the conditions of growth, the production of natural seedlings is only a question of time and of judicious caution.

With self-sown seedlings, there is neither loss of time nor loss in growth, because, while waiting for a seed crop to appear on the ground, the yield is sustained by the reserves, which are thinned out only after the appearance of the seedlings, and until that time form of themselves almost a complete crop.

Artificial re-stocking, never possible except at a high cost, frequently produces crops that have no promise of a future; even in those that succeed best, the individual trees are much too equal in vigour; thinnings in such crops are extremely difficult operations, and shake the confidence of those forest officers who feel most sure of their own powers.

The three successive regeneration cuttings must invariably be made.

The primary cutting should be made close on soils that are merely moist, where there is not much fear of a rank grassy vegetation springing up (this will be generally in the habitat of the sessile-flowered oak); it should be made very close on damp, wet soils, containing a large quantity of clay and vegetable mould, where we may expect long grass (generally in the habitat of the peduncled oak).

If the crop of oak seedlings pre-exists on the ground, the primary cutting must still be made rather close, in order to ensure the production and maintenance of seedlings of beech and hornbeam, the natural companions of the oak; for the young beech is delicate,

while the young hornbeam succumbs under grass and the superficial drying up of the soil.

In case the oak seed-bearers of the reserve are not sufficiently numerous, it is at the time of making the primary cutting that it answers best to put out about 400 small plants, not cut back, per acre; plants cut back would not be so effective, since stool shoots do not come up readily under cover; similarly, to put them out among a self-sown crop of other seedlings would be attended with the risk of seeing them choked.

When making the close cutting, the ground must be cleared of all shrubs and brushwood with which it may be overgrown; so, too, the cover must be raised by cutting away the lower branches of the reserves, without, however, lopping oaks which are not yet mature, and are destined to outlive the regeneration cuttings.

When a large seed crop of beech pre-exists on the ground, and the oak seedlings are either wanting or are completely overtopped by the beech, the latter must be cut back under the cover of the close cutting, in order that the oak may get ahead, as it has a less rapid growth at the start.

If while waiting for a year of seed, the crowns of the reserves were to close up, forming again a continuous leaf-canopy, the state of things as left by the close cutting must be re-established.

The secondary cutting should often be made in two distinct operations, and can never be suppressed with impunity; it is likewise the safest method of diminishing the effects of spring frosts, and of keeping up the mixture of associated trees.

The object of this cutting is to give the young plants more light, while at the same time it protects the soil from being dried up,—which the seedlings alone would be powerless to prevent,—and it hinders the growth of long grass, which must still be considered as a source of danger to the young crop.

Before undertaking this operation it is a requisite condition that the seedlings be sufficiently numerous to form a thicket at the end of a short time (ten years, for instance), and that they be at least three years old; in a forest of oak and hornbeam, however, it may be necessary to make a light secondary cutting, when the crop of oak seedlings alone exists, in which case it will answer the purpose of a primary cutting for the hornbeam, a species that does not easily put in an appearance under a very close cutting.

It is frequently advisable to prune off the epicormic branches of oak and hornbeam; on the former, to prevent the deterioration of the bole; on the latter, because by lowering the cover they injure the seedlings beneath.

The final cutting must not be made until the seedlings have clearly reached the thicket stage, suffice by themselves to keep the ground moist, and have nothing more to fear from spring frosts.

Considered solely from the point of view of regeneration of the forest, the final cutting should remove all the reserves; every oak, however, that is capable of prospering another thirty years at least, must be preserved; the damage they may cause to the seedling crop is more than compensated for by their enhanced usefulness, due to their increased girth. Moreover,

oak seedlings are abundant enough, and they possess only a slight value as compared to these reserves, for while the realization of the former is a question of a far distant future, the latter will be fit to fell in thirty, forty, or fifty years, by which time the want of large oak timber is sure to be generally felt.

It is a mistake to suppose that these reserves are bound to decay. Is it not a fact that many reserves resulting from the method known as "*tire et aire*" (see *infra*) have survived and prospered, though no care whatever was taken of them? A much stronger reason have we then for expecting a similar result with the reserves in question, if we only prepare them for isolation from the commencement and prune off the epicormic branches once or twice, as may be necessary, before they grow too large; besides, those that show signs of decay can always be felled.

Simultaneously with the final cutting a cleaning may become necessary, to get rid of the shoots from old stools, soft woods in case they are too numerous, and any beeches that may chance to overtop healthy and well situated oaks; if birch does not form a complete upper story, it is useful rather than injurious, and in any case it must only be got rid of by degrees, after a previous isolation.

Regeneration obtained within an interval of twenty to twenty-five years between the primary and final cuttings must be considered very satisfactory indeed; this space of time is long only when compared to the shortness of human life.

The regeneration once completed, it only remains

to ensure the maintenance of the oak and constantly to improve its growth. This *rôle* belongs to cleanings and thinnings.

Until the crop has reached the low pole stage, cleanings alone have to be made. Their urgency is in proportion to the richness of the soil and the mildness of the climate. Unless the hornbeam occurs as stool-shoots, it must not be removed in the cleanings, because its growth is slower than that of the oak; but we may remove beech, trees of less importance, soft-wooded trees and brushwood. For instance, on sandy soils it will be the beech that must be specially guarded against; on sandy clays the beech, soft-woods and other inferior kinds; on limestones and calcareous clays, the beech and brushwood. The chief points to attend to are never to create gaps in the leaf-canopy, to top off in preference to cutting back, to make no wholesale extraction of any species that may be got rid of by degrees and with more profit in the thinnings later on, and to set free only as many oaks as are necessary (two hundred to two hundred and fifty, well distributed, per acre). These cleanings are to be repeated as the circumstances require, without striving to make their yield more remunerative by postponing them to a later period.

Thinnings acquire a capital importance whenever the beech is associated with the oak, because they are then merely a continuation of cleanings at every stage. In making them, the end to be attained should be clearly and steadily kept in view, and that is to set free the crown of the oak, without isolating its bole.

To effect this, *contrary to the rules that hold good for thinning a crop composed of a single species*, all beech trees that immediately overtop the oak must be got rid of, while they that are themselves overtopped by the oak must be preserved. They must therefore be commenced early, because if any length of time is allowed to elapse after a crop has once entered the pole stage, every overtopped beech will have died a natural death.

The same course must be pursued in all subsequent thinnings, and beech seedlings that spring up under an already high canopy must be looked after and preserved. These seedlings will constitute an under story, most favourable to the growth of the oak.

But this advantage must not tempt us to endeavour to obtain them in a uniform and absolute manner at a given moment, for that would cause gaps in the oak. The thinnings must be severe round the oak, and of a medium strength over the rest of the crop.

When the associated trees are oak and hornbeam, or oak, hornbeam and beech, the operation of thinning is rendered much more easy. The tree to preserve round the oak is the hornbeam. The only thing to remember is that the hornbeam requires a moderate thinning sooner than the beech. The difference in longevity between the oak and the hornbeam need not trouble us. The gradual extraction of the hornbeam, as it arrives at maturity, will allow seedlings of this tree to establish themselves, as a consequence of the leaf-canopy becoming more and more open.

Only the work must be carried on in such a manner that the seedlings are produced gradually, so as never to isolate the oak. As it is the peduncled oak that is generally accompanied by the hornbeam, it would be a mistake, still more fatal here than in the case of the beech, to endeavour to obtain a regular double regeneration of the companion tree during the life of the oak. Besides a certain number of hornbeam will always live long enough to reach the term of rotation adopted for the oak, and these will serve as seed-bearers in the reserve.

Lastly, if the oak forms only a small proportion of the crop, so much the more reason is there to give them all the room they require. Indeed one of the objects of thinnings is to proportion the number of trees of each kind, and we must not lose sight of the fact, that if in good soils it is expedient to have a large proportion of oak at the end of the rotation, it is the companion tree that should preponderate at the beginning. It is in the operation of thinning, too, that the oaks left standing at the time of the final cutting may be removed as the necessity arises.

It may be of some advantage perhaps, as a sequel to the treatment of the oak, to call attention to drainage works which one may be tempted to carry out. It has sometimes been forgotten that the peduncled oak finds its natural home in very moist and even damp soils; it is the denizen of low lying plains exposed to more or less frequent inundations. Whenever then the water is not stagnant and the soil does not become marshy, it would be a mistake to do any draining. There is no doubt that

premature decay in many places, and the disappearance of the peduncled oak in others, are due to excessive draining. Without altogether proscribing works of this nature, it is allowable to recommend an attentive and previous study of the soil and vegetation. Here, too, we must be cautious, and simply content ourselves with aiding nature in a fair measure. In the majority of cases it will be quite enough to open out a few small channels falling into a well-planned ditch in order to carry off the excess of surface water. It is in localities that remain submerged during winter that the best oak seedlings are often found, the reason being that under water the acorn is preserved.

VII.—TREATMENT OF THE SILVER FIR.

HABITAT.—The silver fir is a widely-distributed species in France, and it covers large areas in Europe. It grows sometimes pure, sometimes accompanied by the beech, the Scotch pine, or the spruce fir. It is principally met with in cold climates, but it inhabits very cold, as well as temperate climates, where, however, it deteriorates. The silver fir requires above all hilly ground of an elevation varying from 1,600 to 6,000 feet; it is there that it attains its largest size, and yields the finest timber; but it is not found indigenous in the plains even in the north of Europe, and the rare instances that are quoted in opposition to this fact are places where it has been introduced by man, or hilly ground in the neighbourhood of mountains, which possesses the same climate.

PECULIARITIES OF GROWTH.—The seed of the silver fir is rather light and its wings enable it to be scattered far and wide; its cover is very thick, and the young plant is very delicate. It remains unharmed under cover up to thirty or forty years of age, and even beyond that. In its true habitat it is not much exposed to spring frosts, but it dreads heat, and is easily killed before it has developed side branches, that is, up to the age of three or four years. The tree throws out a long tap root where the ground is sufficiently deep; but it soon produces strong lateral roots, which allow it to establish itself and thrive in superficial soils and even on rocky ground.

A free, moist soil, of a sandy or calcareous nature is best adapted to the silver fir. It avoids clayey and damp soils, where rot speedily attacks its roots.

The growth of the silver fir is very slow at first, while it is not fairly verticillated, *i.e.*, until about ten years old; from this moment it shoots up rapidly; its growth in diameter is never rapid, remains uniform for a considerable time, and becomes slow again at the age of eighty to a hundred years. At low elevations, and in temperate climates, it shoots up rapidly in height as soon as the first verticel appears, but it dies early.

The silver fir lives for several centuries, and is one of our tallest trees, sometimes attaining the height of 150 feet; its diameter at six feet from the ground seldom exceeds four feet.

USES.—The wood of the silver fir serves a variety of purposes. It is largely used for beams and rafters of houses; its transverse strength is considerable,

and it will bend a long while before breaking; masts for the mercantile marine are obtained from it; and sawn up into planking, it is one of the woods most used by cabinet makers; when split up it is made into household utensils; small slabs of this wood are used for roofing purposes (shingles). It yields a poor firewood, if we except the branches, which contain a few resin cells, and the bark, which contains the numerous resin-ducts. The small amount of resin contained in the stem is doubtless one of the reasons why fir-wood cannot stand alternate states of moisture and dryness.

ROTATION.—For the various purposes above detailed, no distinction is made between the exterior and interior annual rings of growth. The whole thickness of the trunk is used; hence there is but little wastage, and trees of an average girth of seven feet are sufficiently large for all purposes. At elevations below 1,600 feet, or in rich soils and under temperate climates, a rotation of 120 years will produce these dimensions, but in the true home of the silver fir from 150 to 180 years is necessary.

REGENERATION CUTTINGS.—The regeneration cuttings should be conducted as for the beech, remembering that the silver fir, from the localities it inhabits, is still more exposed to damage by the wind; that since the young plant is not out of danger until three or four years old, the first secoudary cutting must not be undertaken before that age; that great caution must be observed as long as the young fir is not fairly verticillated; lastly, that it is better to allow the crop to remain in

a state of secondary cutting, rather crowded, than to run the risk of seeing the wind make a final cutting before the proper time. No one will have the least doubt about this if they will but give themselves the trouble to ascertain for themselves how seedlings grow up under an old forest so dense as to allow scarcely any light to reach the ground. There is no object in leaving any reserves after the final cutting, and moreover it would be almost always impossible to maintain them thus isolated.

It has occasionally been urged that the primary cutting should be made rather open in forests of silver fir, and cases where the operation resulted in success have been cited. If the actual facts are attentively observed and verified, it will be at once evident that, after an open cutting, the young plants that pre-existed on the ground may indeed develop themselves, but that no new seedlings are produced; that the condition of the soil becomes worse and worse, and the seed bearers are blown down by the wind, or wither away standing. It will then be necessary to restock artificially with the Scotch pine or the spruce fir, and the silver fir is lost for the whole of one rotation. These so-called instances of success simply show that there was occasion to make a secondary, not a primary cutting.

IMPROVEMENT CUTTINGS.—With the exception of the beech when it is associated with the silver fir, the sycamore maple is the only species likely to prove dangerous, if it occurs in great numbers; a few willows and elders are also found. In such cases it will be advisable to make a few light clean-

ings, but they will seldom be absolutely necessary, and omitting them altogether has for the most part no further result than that of simply throwing back the silver fir for a time.

Still more for this tree than for any other is it necessary to thin carefully at first. As we have seen, it endures cover for a very long while, and we may add that it becomes vigorous again as soon as light is admitted. Now it is a very common thing for trees to have their leading shoot broken off by snow, hoar-frost, &c., and it is not without some difficulty that such plants reform their crown; which, however, always remains defective. If then care has been taken to preserve all plants that are simply overtopped by others, they will be able to replace those that become damaged. Later on, thinnings of a medium strength must be made so as to interrupt the leaf-canopy in the least possible degree; but with the same end always in view, all suppressed trees, not actually dead in the crown, must be preserved; moreover, their extraction could not possibly improve the growth of the forest. The first to fall should be stag-headed trees. A heavy thinning must never be made, for this reason, that the growth of conifers is seldom accelerated except at the expense of the quality of the timber.

REMARKS.—Wherever I have studied the silver fir, I have come to the conclusion that it is in no way urgent to begin thinnings early. It is a tree that naturally grows in a state of dense canopy, which is favourable to it at all ages. At the same time I have assured myself of the lamentable effects of thinnings

made out of season, or out of reason. So I cannot lay too much stress on this advice, *viz.*, after having conducted the regeneration with great caution, to wait until the stock has reached the higher limit of the low pole stage before beginning the periodical thinnings; up to that point, to take out nothing but completely decaying trees, if their value is likely to exceed the cost of exploitation; and *always* to preserve, as most invaluable, poles that are simply suppressed.

My own private opinion is that it is even frequently advisable to work the silver fir forests on what is known as the selection method; struck with its disadvantages, people have more or less lost sight of the real advantages obtained by this method of working high forests when it is applied in a spirit of moderation, and they have not sufficiently remembered the difficulty of applying the method of thinnings in a mountainous country. This is, however, a question that will be treated of further on.

VIII.—TREATMENT OF BEECH AND SILVER FIR MIXED.

The beech is found naturally associated with the silver fir, and a study of their mixed growth shows the great advantages that always attend it, and proves the necessity of re-establishing it wherever it has disappeared.

The two trees are found in the same soils; their habitats coincide in a certain zone, though the beech extends down into the plains, while in the

hills it is sometimes the one tree, sometimes the other, that ascends highest. Both have a delicate constitution, require to be treated with the same care, and are capable of withstanding the action of cover for a long time, without losing vitality; there is but little difference in their longevity, and they attain their maximum of utility at almost the same age. The produce obtained from the mixed growth is suited for a larger number of uses than what either tree would furnish by itself: the silver fir yields first rate timber for building and manufacturing purposes; the beech yields excellent manufacduring wood and fuel.

Only, in forests treated by the method of thinnings, where we try to regenerate rather large areas going over them in a regular manner, block by block, care must be taken that the beech does not encroach too much upon the fir; for during the first few years the beech grows rather rapidly in height, whereas the silver fir does not begin to shoot upwards until the twelfth or fifteenth year. Later on when the two trees go ahead at about the same pace, the advantages of their association begin to appear; for the side branches of the beech, developing vigorously at all ages, tend to fill up the gaps caused by accidents or by thinnings, and the crop is always more complete than when the silver fir is alone.

ROTATION.—The length of rotation ought to be fixed with reference to the silver fir; for it is this tree that yields the greatest quantity of planking, and planking requires the largest logs procurable if we wish to avoid wastage.

REGENERATION CUTTINGS.—The peculiarities of either of these two trees require the primary cutting to be made close. It is expedient to leave more silver fir than beech in the reserve, whenever the state of the crop allows of this being done; but it frequently happens, in spite of all precautions, that the crop of beech seedlings already exists on the ground, or is produced before that of the fir, and remains living. To remedy this, it is advisable when making the secondary cutting, which should always be effected in more than one operation, to cut back the beech plants under cover of the reserve, or again to postpone the secondary cuttings until these plants have ceased growing in height and are overtaken by the silver fir seedlings; for, in opposition to what is true for the beech, the silver fir under cover always keeps on growing, though it may be slowly.

IMPROVEMENT CUTTINGS.—The moment having arrived for making the final cutting, in case the young beech plants still overtop the fir, it will be necessary to set free a certain number of the latter well distributed over the forest, not by cutting back the beech to the ground, but by taking off the upper part on a level with the lowest verticel of the fir. This operation will generally suffice to keep the two trees at the same height. Simultaneously, if necessary, the cleaning must get rid of the maples and the elder.

Thinnings in a mixture of silver fir and beech must be conducted as for pure beech. Their object will be to improve the growth of the forest and to effect a proper distribution of the two kinds. But it will

no longer be so imperative to preserve firs that are overtopped, for beech will fill up the gaps fast enough. Nevertheless the reservation of such trees, which are not dead in the crown, can never interfere with the development of the crowns above them, and the soil will only be the better covered for it.

IX.—TREATMENT OF THE SCOTCH PINE.

HABITAT.—The Scotch pine is found all over Europe, in the plains, as well as on mountains, but ever preferring cold climates, and yielding wood of a poor quality in a temperate climate. In France it ceases to grow naturally in the plain at the latitude of Strasburg; more to the south it is abundantly spread over high mountains, especially in the Alps and Pyrenees; but it is by artificial means to re-stock denuded ground that it has been introduced into the plains and lower mountainous regions.

PECULIARITIES OF GROWTH.—The Scotch pine is a most hardy tree, growing even in the most barren soils, and only avoiding such as are too argillaceous or peaty. It acquires its finest qualities in dry, sandy soils. Strongly calcareous soils are less favorable to it, and here it could apparently be replaced with advantage by the Austrian pine, at least when nurses are required.

The Scotch pine has a light seed and an exceedingly hardy constitution; the cover of the tree while young is rather dense, but it becomes very light after the age of thirty or forty years. It is a tree that requires a great quantity of light; in consequence we never see its branches interlacing, and in rather

dense canopy, its crown becomes contracted and the tree withers away quickly and dies.

In France the Scotch pine grows rather fast, and even very fast while young, no matter as a rule what be the soil or climate; towards the age of sixty the annual rings diminish greatly in thickness and the growth becomes slow. In its natural home it lives for many centuries, and is a lofty tree, although the diameter seldom exceeds three feet. In a temperate climate and in too moist a soil, the centre of the bole decays after 120 or 140 years, especially if the tree have grown up in a homogeneous crop.

USES.—Scotch pine of good quality, containing a fair proportion of solid resin, yields first class timber for building, whether on shore or on sea. It is in great demand for masts in the French navy, but for this purpose it must have grown slowly and regularly, which conditions alone can ensure great elasticity. In France its growth is too irregular, and its shape generally too faulty for the above purpose; thus it is only used for carpenters' work. Its great durability makes it useful in the construction of bridges. For these various uses, it is essential to remove the sapwood, which often forms a large proportion of the log. It has been tried for railway sleepers; but its sapwood requires to be impregnated, and it is said to have the disadvantage of being easily crushed under a heavy weight. Boat builders on the Rhine work it up into long scantlings for the sides of boats, in which the sapwood is retained in spite of its bad quality. Ordinary planking is also obtained from it. Lastly, of all the conifers, its fuel is the most valu-

able, and is in great demand with bakers, tile-makers, potters, &c.

ROTATION.—To obtain the maximum of usefulness from the Scotch pine it must be allowed to attain a girth of seven to eight feet since the sapwood has to be rejected; this will occur, according to conditions of growth, at the age of 180 or 200 years. But whenever decay is to be feared it will be more prudent to fell it younger, at about 120 or 140 years.

REGENERATION.—In lofty mountainous regions it is often impossible to treat the Scotch pine on a regular system, but in the plains, at a low elevation and on sheltered ground, it adapts itself well enough to the application of the method of thinnings. The greatest difficulty in its treatment arises from the fact that the soil is not well protected, owing to the light cover, and gets hard and cakey, or, if sandy, becomes covered with broom, bilberry bushes and ling. But this is easily remedied.

Whenever, then, the regeneration of a forest of Scotch pine is taken in hand, the primary cutting must be made open, since the seed is light, and the constitution of the tree hardy; that is to say, the intervals between the crowns of the reserve must be three or four yards. In selecting the reserve preference should be given to those trees that have a well-developed head; their roots are more vigorous in proportion, and they are then not so easily blown down by the wind. But, at the same time, it is essential to prepare the ground for the reception of seed. To this end all bilberry and ling bushes must be removed; wherever the slope of the ground is not

too great the stumps of felled trees should be dug out, and if necessary the soil may be lightly cultivated. If the ground is quite bare, it will generally be sufficient to rake it over. In a word, loosening the soil on the surface is the necessary condition for success.

As soon as one or two plants are found on the square yard the sowing may be considered complete; and when they are three years old, and are fairly verticillated, the secondary cutting will be made. About one half the reserve must now be taken out, the other half being allowed to stand until the young thicket is fairly established. In the present case it is not the species that requires the secondary cutting to be made, for the young plant is exceedingly hardy, and fears neither frost nor heat, but the operation is necessitated by the danger that invariably attends too great an accumulation of produce on the surface of the ground. As in the case of the oak, and especially in order that additional age may reduce the large proportion of sapwood, it may prove advantageous to leave a few reserves in sheltered spots at the time of the final cutting.

Improvement Cuttings.—It is seldom necessary to make cleanings in forests of Scotch pine on sandy and dry soils; very few other species are found with it there, and their growth is moreover slower. The birch alone can compete with it in speed, but it is rarely dangerous.

The Scotch pine requires so much light that its branches never interlace, and on that account the periodical thinnings may be made sooner than for other species; but they should be moderate at first,

and should in consequence be repeated more frequently.

They may be commenced then after the crop has reached the sapling stage, and the denser the seedling-crop is at the beginning, the sooner will it become necessary to undertake this operation. When the forest has grown up into low poles the stock must be opened out still further, and a severe thinning must be made when the bole has almost attained its full height. Although one of the conifers, a group of trees whose wood gains in quality by slow growth,* the Scotch pine requires these heavy thinnings, for they alone will enable it to form an ample crown, and thus allow its tissue to become better lignified. In all these thinnings, it is obvious that as far as possible those trees should be removed which are deformed from some cause or another, or which exhibit black spots on the upper part of the bole, a sure indication of an unhealthy accumulation of resin in the woody tissue, and hence of approaching decay.

* This is just the reverse of what occurs among those broad-leaved species alluded to above (*vide* note p. 52) in which the larger and more numerous vessels are grouped together in the "spring-wood." Vessels are entirely absent in the wood of conifers, which is composed of a peculiar kind of tissue (pitted areolar tissue) and short fine medullary rays, and also, in some species of resin-ducts. The wood-cells in the exterior of each annual ring, *i.e.*, in the "autumn wood," are much smaller, thicker-walled and better lignified, than those of the inner portion or "spring-wood." Moreover, here it is the latter that increases with rapidity of growth, the width of the autumn wood being almost constant. A fast grown conifer will therefore show a larger proportion of spring-wood than a slow grown tree under the same conditions of vegetation, while the amount of the autumn wood will be about the same in each. Hence for all conifers the slower the growth, the denser will be the wood.

Vigorous trees are recognized by a thin, bright russet-coloured bark which easily exfoliates and begins rather low down upon the stem.

REMARKS.—During the last forty years many forest officers have abandoned natural regeneration of the Scotch pine, substituting in its place artificial reproduction. They maintain that self-sown crops are not readily obtained, and are a very long time in becoming complete. This idea is the result of insufficient observation, for the truth is this: the old method of cutting down high forest consecutively belt by belt, and leaving no reserves, has nevertheless produced most complete crops; but care was taken to loosen the soil; in Alsace, at any rate, this was so. Since the method of thinnings has been applied this preparation of the ground was discontinued, and unsatisfactory seed crops were the result.

Good seed crops are only found in those parts where, for the last few years, cultivation of the soil has begun again. Moreover, exaggerating the method, they endeavoured to obtain dense crops of seedlings,—a circumstance which is not only rarely produced, but is undesirable, as we shall presently see.

Without in the least denying the facility with which artificial crops of Scotch pine may be raised, it is easy to show the superiority of natural seedlings. From the economical point of view, there can be no two opinions on the subject; from the cultural point of view, it is no less true. Owing to ignorance of the quality of the seed, and uncertainty as to the number of plants that will succeed, sowing is always done

too thickly, and numerous seedlings are generally the result. All of the same age, and of the same height, they crowd one another from the start, and are generally reduced to their terminal shoot with one or two verticels at the most.

Under these conditions, they are never vigorous, and often fall victims to defoliation,—a disease that shows itself towards the age of three to six years. If they escape this danger they are the more liable to the attacks of the Bostrichus and other insects, which devastate vast areas at once. When passing through these numerous dangers, they have grown up into saplings, we only find trees with narrowed crown and slender roots, and thinnings become almost impossible. If they are made light, the trees continue to wither away and never come to anything in the future; if heavier thinnings are made, the lea t pressure on the trees suffices to uproot them.

For this there is only one remedy, *viz.*, to thin out the crop while it is in the thicket stage; but when we consider that this operation would have to be done on a large scale and would be absolutely unremunerative, we shall be convinced of its impossibility. Thus the finest artificial crops have fallen off after the age of thirty years, without the faintest hope of future improvement.

Natural seedlings, on the other hand, less numerous at the outset, are generally completed by fresh falls of seed. The plants being of different heights, do not crowd one another, develop a vigorous crown, and are better capable of resisting defoliation and the ravages of insects. While in the thicket and

sapling stages the future trees are clearly distinguishable; the smaller plants serve to fill up, and assist in cleaning the boles of the taller trees, without any danger of future injury; lastly, not only are thinnings carried out with a more certain hand, but they need not be begun until they pay.

It will now be understood why at the beginning it is not essential to have a very complete stock of seedlings.

The lightness of the seed and the exceedingly hardy constitution of the young plant allow reproduction to be obtained by yet another method, *viz.*, making long and narrow clear cuttings, working gradually in a direction opposite to that of the prevailing winds, and at the same time loosening the soil in some way or another. The only danger will be in the intermittence of years of seed.

Hitherto we have regarded the Scotch pine as growing in a pure state. On this supposition, it is evident that from forty years old and upwards, when the cover has become very light, the soil will deteriorate, and the approaching regeneration will find the same unfavourable conditions that we have already noticed. Most frequently this disadvantage may be overcome by the introduction of indigenous trees as companions for the pine, by which means the growth of the latter is unquestionably improved.

The natural associates of the Scotch pine, whether forming a canopy with it, or growing as underwood, are, according to the climate, the oak, the beech, the hornbeam, and the silver fir. The most important for the improvement of the soil are the beech and

silver fir in sandy soils. Occurring scattered throughout the forest, and towering above a complete under story of the other trees, the pines like oak in broad-leaved forests find a soil that is always moist without being damp; their crowns overtop those of the auxiliary species, and spread out on every side; they are well furnished with leaves, and the woody tissue is well nourished. It is a matter of fact, too, that there is not so much danger of insects as in crops of pure pine.

When the Scotch pine is growing absolutely pure, it will be best to commence the introduction of beech or silver fir, according to local conditions, under crops that have attained the age of forty or fifty years; but we must not overreach the object in view, and the proportion of the tree we introduce must be regulated accordingly.

The Scotch fir is a species that may be termed an invader, and notably in the forest of Haguenau, it has supplanted the broad-leaved trees, thanks to clear cuttings. In these soils, which are too rich for it, its regeneration is made more difficult, owing to an abundant growth of grass. It should there be made gradually to give way to the oak, which in that forest yields the most valuable produce, while the pine, being at its extreme southern limit in the plains, yields an indifferent quality of timber.

Hitherto but few cases have occurred where regeneration of this pine associated with other trees has had to be undertaken, but where such a case has occurred, the regeneration cuttings were conducted (and rightly so, as it would seem, since the results

have been successful) as though the companions of the pine alone were present. The only difference was that the secondary cuttings were made before a complete crop of seedlings of those species was produced, thus enabling the pine to come up in the blanks.

X.—TREATMENT OF OTHER CONIFERS.

The spruce fir and the larch, the mountain or dwarf pine, the Corsican, Aleppo, Cembran, and cluster pines, growing either pure or mixed, cover large areas in France. But among these the spruce fir, the larch, and the Cembran and mountain pines almost always occupy such high regions, that it is impossible to treat them by the method of thinnings. In their case, the selection method, which will form the subject of the next chapter, should generally be employed.

The Corsican pine is chiefly met with in Corsica, where hitherto its exploitation has been carried on only in places, and without any definite rules. But what we know of it leads us to conclude that the treatment adopted for the Scotch pine will suit this species also.

The Aleppo, and notably the cluster pine, are often cultivated for the sake of the resin they yield. Thus their exploitation is governed by certain rules, which may be found in special works on the subject.*

The Austrian pine is not indigenous in France, and its introduction amongst us is too recent to permit us to lay down any rules for its treatment.

* The tapping of the cluster pine for the sake of its resin is fully described in the Supplement.

CHAPTER III.

IRREGULAR HIGH FOREST.

Our irregular high forests are the consequence of two principal methods of treatment,—"*Tire et Aire*," and the selection method.

"*Tire et Aire.*"

The method known as "*Tire et Aire*" has not been applied to high forest in France for about the last fifty years. It will be enough for us then to say in what it consisted and to appreciate its results. In this method of treatment, high forest was so worked, that equal areas were cut over every year successively in the order in which they follow each other on the ground; the forester never returned to make improvement or any other cuttings, and ten trees were left as reserves on a forest "*arpent*," or eight trees per acre. The rotations adopted were generally long.

Thus, then, nothing was done either to obtain natural reproduction or to ensure the maintenance and improve the growth of the valuable species. But owing to the length of the rotation, seedlings appeared under the old crops, as soon as these began to admit a little light, and maintained themselves, thanks to the high cover which resulted from the forest growing up in a state of leaf-canopy during a long period of time. Nevertheless, in climates and soils favourable to the beech, this tree frequently took possession of the ground to the detriment of the oak, which, in addition, had to struggle against the soft-woods that are so numerous and vigorous in

temperate climates and in moist or damp soils. Hence, because no cleanings were made, the oak disappeared to make way for secondary or inferior species, and the absence of thinnings did not allow the few individuals that chanced to remain living either to develop a good crown or to attain the most useful size.

Even in a mild climate, where soft-woods are rare and the beech and hornbeam less at home than the oak, this tree, while remaining in possession of the ground, only yielded soft timber well adapted for planking, and for all purposes in which split-wood is required, but unsuited for large constructions.

A mere statement of these facts is enough to show that the method of "*Tire et Aire*" was defective in its procedure, and was bound to result in irregular crops. In the application want of skill frequently rendered matters still worse. Thus it was that a committee charged with the revision of forest matters, not being able to explain the disappearance of the oak, attributed it to the rotation being too long. They then ordered it to be reduced to sixty or seventy years, in the hope that shoots from the stool might complete a crop of natural seedlings.

Moreover, the exploitations were often confined to the vicinity of roads, in localities where the produce found a ready sale. The remainder was left intact, and as the area cut over every year was constant, being equal to the whole area of the forest divided by the number of years in the rotation, crops were cut before their term of exploitability was reached.

Another defect which may be alleged against the

method of "*Tire et Aire*" is, that it neglected all consideration of the requirements of different species, as well as of their various uses. An entire forest was treated as a single working circle, and the cuttings followed each other on the ground rigidly in successive order; so that all trees, without distinction, were felled at the same age, frequently to the detriment of the usefulness and quality of the timber produced. Moreover as thinnings were unknown, the yield was relatively small.

Lastly, no matter how precise were the regulations of the Statute of 1669, the forest officers did not always obey them. According to individual caprice, the reserve was more or less numerous than the quantity prescribed; and even if no disadvantages followed when the reserve consisted of oak, the same cannot be said when the tree which they reserved had a thick cover.

I must say I cannot see that the mere existence of these reserves above the underwood was a cause of irregularity. The crop that resulted was not homogeneous, but it was not irregular; if this were true, coppice with standards would be an irregular forest. Their preservation was even perfectly justifiable; their object was not to effect natural reproduction, but to produce timber of exceptional size, necessary for certain uses. Their utility is so great that rules are laid down to do as much when making final cuttings in the method of thinnings. Only in this latter case care is taken that these reserves shall consist exclusively of oak, which may be cut down when they begin to decay, or as soon as

they have reached the maximum of utility, without waiting until the end of the new rotation.

By the side of these signal disadvantages, we must, however, acknowledge that the method of "*Tire et Aire*" admitted from its very nature a grand order in the exploitations, and that this order is to a certain extent indispensable to the success of all exploitations. Thanks to the long rotations, it has often bequeathed to us forests rich in standing timber, and if cleanings and thinnings had been made in oak forests, there would not have been much fault to find with it.

At the present day, all the high forests to which this method was formerly applied have been regularised as far as that was possible, and it only remains to carry out in them the operations of the natural method.

SELECTION METHOD.—The selection method has chiefly been applied to forests in mountain tracts stocked with beech or the conifers (silver and spruce firs, Scotch pine, larch, &c.). These species are not all alike in their requirements, and naturally the method of treatment must vary with each of them. It may be stated, however, in a general manner, that the selection method consists in felling here and there, wherever they may chance to be found, trees that are dead, decaying, unsound, or past maturity, and a few others that are still healthy to meet the demands of the market. In this method of treatment the point to be aimed at is only to fell very few trees on any one spot, and to spread the operations every year over a large area, if not over the whole forest.

According to the special requirements of each species, its constitution, and its facility of withstanding the action of cover for a longer or shorter period, the trees are to be felled singly or in small groups of three, four, up to seven or eight. The result is that high forests, worked on the selection method, present a confused collection of trees of all ages and sizes, or a patchwork of small, almost uniform clumps scattered about in no definite order. This condition of things occurs only when the annual yield is fairly equal to the annual sum of production. If the former is less, then the forest gets gradually filled up with old trees, and the younger stages of growth almost cease to exist, while if the annual yield exceeds the sum of production, the stock again tends to become uniform, but this time with the younger stages of growth. Occasionally, too, the exploitations restricted to the wants of local markets by the difficulty of exporting the produce to any distance, have given rise to forests in which old trees are exceedingly numerous, presenting an appearance of old quasi-regular high forest. But this condition of things is now seldom to be met with; as a rule, improved lines of export have enabled this accumulated wealth to be realised; at times the annual production of the forest has even been exceeded, and exploitable timber is no longer found in sufficient quantity. Strong winds have in some cases regularised the appearance of the forest, by blowing down all the tall trees.

VALUE OF THE SELECTION METHOD.—From what

precedes, it is easy to show the inferiority of this method to the method of thinnings.

The quality of the timber produced is inferior. For the young trees are overtopped by the higher ones, and do not emerge into the top-story until they have passed through alternate periods of suppression and unimpeded growth; the result is, that the annual rings are of unequal size, and this leads to a want of homogeneousness and elasticity. Trees of the same height do not grow side by side so as to form a leaf-canopy, and their branches remain a long time on the bole, producing many large knots in the wood. The felling of trees, scattered about in a crop that is always complete, must of a necessity injure the trunks of their neighbours by tearing off branches or bruising their bark; now in the case of conifers, these wounds heal up with difficulty, and, cause internal decay. The removal of the produce injures in the same manner the lower part of the bole.

The quantity of the produce, too, is less; for this method is incompatible with the execution of thinnings, and by that fact alone there is a clear loss in material.

Lastly, as far as regards the management of the forest, it is evident that as the exploitations are carried on every year over a large area, supervision becomes a matter of extreme difficulty, and is often ineffective.

Nevertheless, side by side with these defects that we have just pointed out, the selection method presents some important advantages; it ensure-

reproduction and the association of different kinds of trees better than any other method of treatment. These advantages are so great that it must often be adopted for reasons, not numerous in themselves, it is true, but the necessity of conforming to which frequently arises.

TRANSFORMATION OF FORESTS WORKED BY SELECTION.—Whenever atmospheric influences are no obstacle to regeneration, and the soil is placed under favourable conditions, such forests should always be transformed into regular high forest and worked by the method of thinnings. But the disadvantages attached to the selection method have been recognised for many years, and transformation has ever since been undertaken wherever it was possible. Indeed people have in this respect gone so far that in many places where experience has proved the danger of endeavouring to obtain a regular regeneration by successive areas annually it will be necessary to bring back the forest into its former state.

Whatever be the particular method adopted, the transformation of forests treated by this method comprises two cultural operations, which must be carried on simultaneously: the regeneration of a certain portion of the forest, and the continuance of selection over the remainder. But thinnings cannot be allowed, except in such parts as are already transformed, or in those that already present a certain degree of uniformity and which, when the time fixed for their regeneration arrives, we may expect to find in a flourishing condition.

The regeneration cuttings that must be carried

out in the first periodic block will differ from the ordinary cuttings, in that the chief aim should be rather to take advantage of already existing seedlings and to blend them together, than to obtain new ones. From this point of view, it is evident that crops in the various stages of thicket, saplings, and even young poles can grow up side by side without inconvenience to each other; the differences in height will disappear in course of time. The only places where we may endeavour to obtain new seedlings are in spots that are blank or covered with dwarfed plants; but it must not be forgotten that the silver fir and the beech are endowed with the property of shooting up vigorously as soon as they are uncovered. Each annual cutting may thus vary in its nature from point to point, resembling here a primary cutting, there a secondary or final cutting, according to the condition of the underwood. In a word, it is not nearly so important to look for immediate regularity, as to obtain a crop in a promising state of growth which may be regularised during the subsequent regeneration.

The selection fellings over the remainder of the forest must be confined solely to taking away all trees that are dead, unsound, or completely decaying, while preserving any trees that are only just mature, or are still flourishing, no matter what be their size. The wants of the market will be abundantly supplied by the operations in the first block. As the selection fellings will pass through the forest every year, or at any rate at short intervals, opportunities of removing old trees, as soon as they are thoroughly

mature, will always occur. By this method, the number of the old trees will constantly go on increasing, and the transformation will more and more resemble a regular regeneration.

We have stated that no thinnings are to be made, and this for the following reasons: it must be remembered that we are operating on crops where the ages are mixed together in the most confused manner. The stock can be kept complete only on the condition of preserving suppressed trees, as well as those that overtop others, and the former are necessary in order to replace the latter, in case these succumb to some accident. Moreover, thinnings cannot be justified, except to establish a certain uniformity of age, and frequently this could not be done except by sacrificing trees in full growth, which are the birthright of generations yet to come. To give up to the present generation the sum total of production, would be to allow it to abuse its right of usufruct. Lastly, while compromising the future of the forest, we should be acting directly contrary to one of the three objects that a rational method of working forests should always have in view, *viz.*, a steady yield.

It is worth while to remark that the rotation, in the course of which the transformation is to be effected, should be equal to the normal or regular rotation. For, at its expiration, we should be in a position to find timber that will be exploitable, not only at the commencement, but during the entire length of the second rotation.

MAINTENANCE OF THE SELECTION METHOD.—We

have already said that the selection method, should be kept up for exceptional reasons. It ought to be maintained in all forests where protection of, or shelter to, other parts is the chief object, and wherever regeneration is uncertain, difficult, or too slow to enable us to obtain it with certainty, in a regular and complete manner in a given space of time. The same rule holds good for forests of very small extent.

As far as protection is concerned, this method should be employed whenever there is reason to fear landslips, avalanches, and the formation of torrents, or where the wind is violent and always blowing, as at the higher limit of vegetation, on mountain ridges, &c.

Regeneration becomes difficult and uncertain when the climate is extreme, or the soil unfertile. The climate may be extreme in itself (higher limit of vegetation), or from the absence of shelter (mountain passes, ridges, edges of the forest). The soil is unfertile from its nature (rock, scattered blocks, stones), or owing to a steep gradient (wherever one cannot walk with a sure step). These circumstances may co-exist, and result in a stock that is seldom complete and generally more or less broken up by gaps. They are found in about half the hill forests of conifers under the administration of the Forest Department.

In all these circumstances, the existence of constant leaf-canopy is imperatively demanded, and to maintain this, the action of nature, which gets rid of the trees one by one, has to be imitated. In a word,

the selection method must be employed, only the trees must be removed when they are still capable of furnishing useful material.

APPLICATION TO THE VARIOUS SPECIES.—The forests which require to be treated by this method are stocked with silver fir, beech, spruce fir, larch, and with various species of pine. The young plants of all these trees require different degrees of light, and thus the treatment must necessarily be modified for each special case.

SILVER FIR AND BEECH.—The silver fir and the beech are capable of withstanding the action of cover for a very long while, and for many years preserve the property of shooting up again with vigour when they are uncovered; an underwood is always found under old trees, that may be utilised by removing the latter one by one. In a forest of these trees, the stock can remain throughout as full as possible; hence it must be so kept, for this result is the chief object in view in forests subjected to this system. Besides it has been constantly observed that there is great danger in cutting out too much from crops of silver fir: the wind is always rocking the trees on the edges of the gaps made to and fro; if not blown down, they dry up standing, and the blank gets ever larger and larger. Perhaps, too, this may be the effect of an insolation which trees that have hitherto lived in full leaf-canopy are unable to resist. The selection method must frequently be applied to silver fir forests above an elevation of 2,000 feet if they are unsheltered on the side from which dangerous winds blow.

SPRUCE FIR.—Although the young spruce fir generally avoids heat, it only comes up well on the edge of the forest, and in rather open spots where the light is sufficiently abundant. Crops of this tree form an exceedingly dense canopy and the removal of trees one by one would not produce sufficiently large gaps to ensure the maintenance of seedlings. Hence three or four trees must be removed from the same point; only care must be taken that these small gaps are not situated too near to each other, because when the spruce fir grows in leaf-canopy, its roots are short as well as superficial, and it would be extremely dangerous to allow access to the wind.

Attempts have at times been made to apply the method of thinnings to the spruce fir. Without denying that this may be possible in well sheltered localities, I am of opinion that it is always very rash to do so, at least in France. For this tree exclusively inhabits mountains and even high mountains (it is seldom found naturally in the Vosges, becomes more abundant on the higher plateaux of the Jura, and is only common in the Alps). In all these situations it is exposed to violent winds, which it cannot resist when it has grown up in dense canopy, and is then isolated. Now the regular regeneration cuttings always imply the idea of interrupting the stock over rather wide areas at a time.

In Switzerland, where the spruce fir is very abundant and is found rather low down towards the plains, a special method has been sometimes adopted. The forest is divided into several working circles, or divisions, and a very narrow clear cutting is made in

one of them. Next year the same is done in another circle, and a rotation of the various circles is so arranged that the same point is revisited every four or five years. The neighbouring portions of the forest are relied upon to refill the area cut with seed. This method may answer when the cutting coincides with a year of seed. But under the climates and in the damp soils that suit the spruce fir, the ground becomes rapidly overgrown with numerous weeds, and it is often a long time before a seedling crop appears, unless recourse is had to artificial re-stocking.

HARDY CONIFERS.—When the forest is stocked with larch, the Scotch or the Corsican pines, seedlings will not be produced, and above all will not prosper, unless they receive plenty of light. The gaps made for the spruce fir will be no longer sufficiently large. Hence the selection fellings must be still further concentrated, and eight to ten trees must be removed from the same spot, so as to create small blanks of about 400 square yards; it will be advisable to slightly loosen the soil over these small blanks, in order that reproduction may be better ensured. Only they must not be made too near together, otherwise the forest would become a complete chess-board, and the wind might get in and prove mischievous. Whenever it is possible, it would be an advantage to split up the forest into several groups, to operate in each successively, and as its turn comes round, so to locate the fellings that they may succeed each other in the order of their respective dates.

In the valley of the Adour, some forests of pure oak are worked on the selection method. But these are forests which are open to grazing throughout their whole area from one year's end to another, and in which therefore it would be useless to look for self-sown seedlings. Hence after the old mature oaks are felled, tall saplings as high as thirteen to twenty feet are planted out in the gaps. By this method they obtain trees with well-developed crowns and tough-grained wood, but of no length of bole.

GENERAL RULES.—It is obviously very difficult to lay down precise rules for working forests on the selection method; they depend entirely on local conditions. Still some that will be found generally applicable may be formulated.

Selections are to be continued as heretofore, that is to say they should extend every year over rather a large area. Only to avoid returning too often to the same spot, a proceeding that always injures the crop, and becomes a very difficult task for the forest officer, it is advisable to divide the forest into a certain number of compartments, five to ten, each of which is taken in its turn successively.

In order to render the yield of each year as nearly equal as possible, these compartments should be made either equal in area or equal in fertility. Too much importance, however, is not to be attached to this point, and a certain approximation will be quite sufficient.

From each of these compartments, timber that is deemed exploitable will be removed, that is to say, in the case of imperishable proprietors (the State,

bodies corporate, &c.), trees that have reached maturity; in private forests all sound trees above a fixed minimum girth, including those that are dead or completely decaying or unsound. The number of trees removed will vary with the special requirements of each kind, for each of which it will be a constant figure. This is the rule laid down in the old instructions for working the silver fir forests of the Jura and Vosges; it is besides no more than the intelligent application of Article 72 of the Statute of 1827, in which the word "age" stands for "condition of growth." This method of fixing the annual yield possesses moreover the great advantage that it enables one constantly to aim at bringing the forest into any condition desired, and it would be unreasonable to expect to obtain by the selection method a more vigorously steady yield than we get from coppice with standards, in which the annual yield is based on area with all its chances of error.

As it is the selection method that has to be kept up, no thinnings must be made. For in thinnings, the suppressed trees are removed, and thus the stock must necessarily become regular. But short trees may be slightly pruned when their lower branches overtop a well formed underwood.

In the case of the silver fir, and more especially in that of the spruce fir, it will be advisable to cut away the dead branches which remain a long while on the bole before falling off. They form a sort of bolt in the wood that has no connection with the adjoining parts, and, when the timber is sawn up,

considerably reduce the value of the planks. But care must be taken not to cut into the bark, for this would cause the resin to ooze out, and would result in the formation of decaying spots at least as injurious as the dead branches.

CHAPTER IV.

COMPARISON OF THE DIFFERENT METHODS OF TREATING HIGH FOREST.

It may be said that the selection method is a method of working high forest which most resembles the action of nature. Its advantages are, that it ensures the constant maintenance of the leaf-canopy, and makes reproduction absolutely certain; it ensures too, better than any other method, a proper admixture of different kinds of trees. Local conditions frequently render it a matter of necessity. But because thinnings are never made, the quantity of the yield is less, and its quality is often inferior. An exaggeration of the method may lead to the ruin of the forest, for the yield is not fixed, and no order whatever is observed in the exploitations.

An absolute order in the exploitations was the principal aim in the method known as "*Tire et Aire.*" The length of the rotation preserved the existence of the forest, but it only succeeded for certain trees, and in mild or temperate climates. Here also the produce obtained was inferior in quantity and in quality, and the new crop after the regeneration cut-

ting, was composed of all and any kinds of trees at haphazard, and was sometimes incomplete.

The method of thinnings is adapted to all species, and directs the action of natural forces to suit the wants of mankind. It allows us to obtain the most useful produce in the largest possible proportion; it permits us also to dispose of it conveniently as soon as occasion occurs, and as soon as it can be realized.

Its essential objects are speedy and regular natural regeneration, the best proportion between the associated species, and constant improvement of the produce. As much order as is expedient and possible may be obtained by this method.

It is thus a considerable step in advance, but it requires much nicety in its application, and demands constant attention and *savoir-faire*. Clumsily applied, it may compromise the reproduction and the yield in the highest degree. For example, in mixed silver fir and beech, when a moderate operation on the selection method would have ensured reproduction and kept up the association, a primary cutting made too open, cleanings neglected, or thinnings exaggerated, compromise the existence of the silver fir, sometimes even that of the forest itself, or in any case diminish the usefulness and the quantity of the produce. So too, ill-conducted regeneration cuttings may compel us to re-stock large areas artificially, with a considerable loss of time and money. Thinnings exaggerated or carried out under fixed ideas may hinder, under pretext of assisting, a regular growth, or bring about a faulty distribution of associated species, cause an indigenous tree entirely to

disappear, and reduce the forest to pure oak. Lastly, to speak generally, it is not easy to obtain natural reproduction except in canopied forest of mature age, and it is always extremely dangerous to try and obtain it prematurely.

These dangers are not inherent in the method, for the method is not defective, but they arise from mistakes in its application. The fact is that this method makes the action of the forester only too easy; and if he is not imbued with sound ideas of forest culture, or if he is wanting in activity and, above all, prudence, he may commit faults that a century will scarce suffice to repair.

The true forester will studiously avoid all wholesale operations, unless they are clearly called for by the circumstances of the case. Thus, when undertaking regeneration he will get rid of all undergrowth, but he will preserve it in every other case; so again when making a cleaning or a thinning, he will avoid the wholesale extraction of birch or other indigenous and useful trees; in a thinning he will preserve overtopped plants that can survive a while longer; lastly, in a primary cutting, unless there are distinct reasons for making it open, he will make it close. He must never act at haphazard. If he is at all doubtful of the result, he will hold his hand and leave nature to herself. He must remember that if he can sometimes guide her course, he ought never to substitute for it systems based on foregone conclusions.

PART III.

COPPICE.

We have already seen that a coppice is a forest which is reproduced principally by means of stool shoots or suckers. This is equivalent to saying that the broad-leaved species alone are adapted to this system of working.* The system of coppice includes two methods of treatment: (i) Simple coppice in which no reserves at all are left, or, if any are preserved, they are not intended to stand for more than two rotations of the underwood; (ii) coppice with standards or stored coppice, termed also "high forest over coppice" or "coppice under high forest," in which the standards are preserved for not less than three rotations of the underwood.

CHAPTER I.

SIMPLE COPPICE.

In France simple coppice is grown on rather a large scale, but it is for the most part in the hands of private proprietors. The communes, however, possess about 750,000 acres of it; but it is only under exceptional circumstances that the State adopts this treatment. Article 70 of the Statute of 1827, which applies to all woodlands under the control of the

* See ante, p. 16.

Forest Department, interdicts it so long as a special statute in the shape of a working-plan does not expressly direct otherwise. The importance of simple coppice has declined to a remarkable extent within the last thirty years, especially since foundries have used coal for smelting purposes. Generally speaking, the price of fire-wood, far from following the rise in price of timber, has at the most remained stationary, and in many cases has even fallen. Private proprietors themselves obviously find it to their interest to grow coppice with standards, wherever the materials for a reserve of valuable trees exist, and it is only considerations of the kind of tree that is grown, of the soil, or of the growth of special kinds of produce that can justify the adoption of simple coppice.

For instance, the holm oak does not in France attain the dimensions of timber; on the other hand, its young bark is excessively rich in tannin, and is of the very highest quality for the manufacture of leather. The sweet chestnut is not indigenous in our country; at an age when it might yield large timber, its heart wood is nearly always unsound. Grown in simple coppice with short rotations it is in great demand for cooperage and for making props in vine-growing districts. Here any reserves that may be left would be regarded as fruit trees. Similarly in agricultural districts and in the neighbourhood of mines, it is also possible that it would pay to grow the two oaks (the peduncled and sessile-flowered varieties) as simple coppice, whether it be for training poles, or for pit-props, or for their bark.

But it very rarely happens that the demand for timber is not large enough for coppice with standards not to be here also the preferable method of treatment. The exception will occur only when there is too little soil to produce a bole of sufficient length, twenty feet at least. In this case as well as on warm aspects it is obviously better, in the interests of the community at large, to grow high forest with trees adapted to the soil and the climate. But conversion is an operation which the State and perhaps a few communes alone can undertake, and simple coppice has thus its complete justification.

The essential points to study in the treatment of coppice all aim at ensuring the production of shoots and the maintenance of the tree which is being grown. They relate to the manner in which each species coppices or throws up suckers, to the length of the rotations, to the most favourable season for exploitation, and to the manner of felling, cutting up, and removing produce.

ORIGIN OF THE SHOOTS.—The shoots may originate in two different ways: they may be derived (i) from adventitious buds, or (ii) from dormant buds. Adventitious buds are formed after the tree has been cut down, on a little swelling or excrescence between the bark and the wood. Dormant buds are old buds that have not hitherto sprouted from want of sufficient light, but which, without developing leaves, have continued to live on, traversing at the same time each successive annual ring of growth. Their extremity even passes through the bark as far as the thin outer layer. The point

whence they proceed is the medullary canal itself; they are therefore of the same age as the part of the trunk on which they are found.

Hence, the shoots which are derived from adventitious buds present themselves on the cut surface of the stool, between the bark and the wood; the other class of shoots spring up below this section and make their appearance after piercing through the bark. These latter are by far the most numerous. On their number, as well as their less or greater vitality, depends for the most part the aptitude of a tree to reproduce itself from the stool. The thickness and hardness of the bark have nothing to do with it.

Besides these stool-shoots, a certain number of trees also throw up suckers or shoots from the roots. It is even remarkable that some of them, though they coppice badly, produce suckers in abundance, and are thus invaluable for keeping up the underwood. The fact is that suckers are rooted directly in the soil, and are hence independent of the parent stool from the very beginning, a circumstance which, in the case of stool shoots, occurs only when they are in contact with the soil.

The trees which reproduce themselves most freely from the stool are the oaks, the hornbeam, the elms, the maples, the sweet chestnut, the common alder, the ash, the willow, &c.

The trees most apt to furnish suckers are the holm, the Pyrenean and the cork oaks, the aspen, the white alder, the lime, the willows, the birch, &c.

A certain number throw up both shoots and

suckers, as the sweet chestnut, the elms, most of the fruit trees, the ash, the evergreen oaks, the Pyrenean oak, the lime, the willows, &c.

The beech very rarely produces suckers, and most of its stool-shoots are derived from adventitious buds; moreover it ceases to coppice at an early age.

ROTATION.—The length of the rotation has a marked influence on the number and vigour of the shoots. As far as reproduction alone is concerned, it may be said that there is no minimum length for the rotation, for the younger the coppice is cut the greater are the chances of finding the dormant buds still alive and vigorous.* But actually there exists an inferior limit lower than which no one ought to go: this is the age at which the standing crop attains a marketable value and offers an advantageous investment. It is easy to understand that this inferior limit varies with different trees, and that if a willow bed may be cut every year or every second year, the same does not hold good for a plantation of sweet chestnut, which cannot be cut with profit before the tenth or fifteenth year. A simple coppice of alder or of the two oaks, ought not to be cut before the age of twenty-five or thirty years.

Article 69 of the Statute of 1827 fixes, for State forests, a minimum rotation of twenty-five years,

* This remark requires a slight qualification. Very young and small stools throw up not only fewer but weaker shoots than older stools in the full vigour of their vegetation. Who in India has not observed the repeated efforts of a young stool till at length it throws up shoots strong enough to resist the forest fires? Many of our so-called seedling trees of the broad-leaved species have originated thus.

those forests being excepted in which the dominant kinds are the sweet chestnut and the soft-woods, or which are situated on the worst kinds of soil. Article 134 of the same Statute renders these provisions applicable to Communal forests. This is an excellent measure, which private proprietors themselves would, almost always, find it their interest to adopt.

But though there may be different views regarding the inferior limit of age at which a coppice ought to be cut, experience has clearly laid down a superior limit generally for all kinds of trees. It is obvious that reproduction from the stool ought to be completely guaranteed, and for no kind is it ever safe to exceed the age of forty years.*

ANNUAL YIELD.—If the working-circles have been properly laid out, the crop on the ground will be sufficiently homogeneous to enable us to base the annual yield on area, and the determination of the number of acres to cut every year becomes a very simple matter. Moreover, this is the only certain method by which we can work the forest on a given rotation.

SEASON FOR CUTTING.—Under this head we must examine the two cases of felling during the winter and felling while the sap is in circulation.

The first condition for the production of shoots

* This remark, true for France and Europe generally, must be accepted with some slight modifications for India. The teak is a remarkable case in point. Stools on which more than 120 rings were counted (and there is nothing to prove that each ring is not one year's growth) produced in many instances, although cut down to the ground, more numerous and larger shoots than the surrounding younger stools.

is that the bark should thoroughly adhere to the wood. If this union is destroyed, the little excrescence, on which adventitious buds appear, cannot be formed. In the same manner, if the dormant buds, the extremities of which are contained in the whole thickness of the bark, have been broken, the chances of shoots coming up are considerably diminished.

In order to preserve this union no cutting should take place before the winter sets in, as the autumn showers may cause water to permeate between the bark and the wood; and if frosts then follow, a disruption is the consequence. Similarly no cutting should be made during severe frosts, because at such times the adherence between the bark and the wood is slighter than at other seasons of the year, and the former is liable to split under the blows of the axe.

On the other hand, cutting while the sap is active is considered to possess the defect of producing fewer and less vigorous shoots, which moreover are exposed to early frosts before they are properly lignified, and above all of causing the loss of one year's growth.

Arguing thus, felling operations would have to be restricted to a very limited period, viz., from the beginning of February to the end of March. It is easy to conceive that this time is too short, and would suddenly require a number of hands impossible to procure all at once. More than this, it would possess the very serious defect of throwing out of employ all the labourers who take to wood cutting during the winter.

But though it must be acknowledged that the shoots are most numerous and vigorous when felling operations have taken place in February and March, especially if the spring is sunny, still we must not exaggerate the disadvantages of cutting at any other time of the year.

The fact is that the general climate of France is temperate; it is only in exceptional situations that severe cold need be feared, and even this only at rather long intervals. There is hence no serious drawback in beginning felling operations in autumn, as soon as the sap has become inert; they may be continued throughout the winter, except during severe frosts, when, however, all out-door work is impossible.

Cutting while the sap is in circulation is always to be deprecated, but it seems to us that its effects have been inordinately exaggerated. It is true that the shoots make their appearance only at the next rising of the sap (*i.e.* about August), and in coppice where the practice of surface firing* prevails, even as late as the ensuing spring. But it is exceedingly difficult, when the rotation consists of twenty or twenty-five years, to appreciate the difference of volume resulting from one year's growth more or less. Nor is it proved by observation that coppices grown for their bark, which are cut over while the sap is in circulation, produce less ample or shorter lived clumps of shoots, except as the result of an exceptionally hot summer and of long continued drought. The worst effect of cutting while the sap

* See *infra*, p. 124.

is in movement appears to be the inferior quality of the wood obtained.

MANNER OF CUTTING.—The way in which the stools are cut, exercises, beyond all contradiction, more influence than anything else on the production of shoots and the well-being of the coppice. We must take into consideration the kind of implements to use, as well as the shape to give to the surface of section and the height at which the stool should be cut. In every case, care must be taken not to split the stool or disunite the bark from the wood, so as to prevent water from permeating through between the two.

Instruments with a cutting edge are to be preferred to the saw, unless it be for stools which are too old to give any promise of shoots. The truth is that the saw does not cut but tears, and is hence liable to separate the bark from the wood. Moreover it produces a gnawed surface, which, acting like a sponge, retains moisture and thus favours its infiltration into the wood. The water, which collects on the stool, hastens its decay; it may cause rot at the foot of the shoots which grow over and englobe the stool, and prevent the production of shoots at the next felling, or, to say the least, affect their vitality. This danger ceases to exist for small stools; the growth in diameter of the shoots shields them from the action of the atmosphere before decomposition sets in. But there is seldom any advantage in using the saw, as it requires more time for poles of the thickness met with in a coppice. It is only in the case of trees capable of furnishing large tim-

ber that the saw is advantageously used, as it then saves all the wood which would otherwise fall in chips under the axe. But in that case the production of shoots is no longer the object proposed.

The axe or hatchet and the billhook are the cutting implements most frequently employed. The billhook is used with one hand only and hence requires less clear space. The shock it produces is slighter than that caused by the axe. For this reason it ought to be employed for all poles under two inches in diameter, in order to avoid shaking the roots. Otherwise the fibrous roots would run the risk of being broken, and the vitality of the stool endangered. The axe is suited for trees of a larger diameter.

Whether the billhook or the axe is used, it is always necessary to take the precaution of cutting the bark right through up to the wood on the side opposite to that on which the woodman finishes cutting. The object of this is to avoid the risk of having the bark torn off and to preserve the roots entire.

The surface of section ought always to be clean and slightly inclined, so as to allow rain-water to run off easily. For this purpose it ought to slope only in one direction: it should not be hollowed out in the centre. If the tree has been cut to the right and to the left, so as to leave a sort of gutter in the middle, the stool ought to be levelled down.

The stool should always be cut down to the ground. The only exception to this rule is when the locality is flat and low and subject to frequent

inundations. In that case the stools ought to be cut just a little higher than the level usually reached by the water, so as to prevent their being covered. The advantages of cutting down to the ground are very great. As the most numerous shoots are derived from dormant buds, by cutting the stool in the manner indicated, they spring up from under the ground, or at least in contact with it. This serves them as a *point d'appui*, without which they could not resist the force of the wind and the weight of superincumbent snow or hoar-frost. But the chief advantage lies in the fact that they will develop their own roots and thus become entirely independent of the parent stool.

In this way may be explained the, so-to-say, indefinite duration of simple coppice containing no reserves, unable therefore to renew themselves by seed, and in which, from time immemorial, planting up has never been resorted to. Moreover, this fact may be directly observed in all coppices. Frequently clumps of shoots may be seen entirely independent of each other, but arranged in the form of a circle of variable diameter. These clumps are derived from a single original stool, the centre of which has disappeared. This phenomenon may go on from the formation of the clump, in the middle of which the old stool is still to be seen, till the shoots become quite separate owing to its gradual decay. This circle, which is sometimes called a fairy ring, goes on increasing until there is room enough in the middle for shoots and fresh stools. The arrangement then becomes indistinct, and is not easily recognised.

Sometimes when the trees belong to those kinds which throw up suckers, they are cut below, *i.e.*, *in* the ground. Some forests are actually worked in this manner, and in consequence the clumps consist of stems which spring up directly out of the ground. But this method ought not to be generalized before there is perfect certainty that the result will be the same as in those localities where it has been hitherto practised.

CUTTING UP PRODUCE.—In order not to obstruct the development of shoots, and above all not to injure them at a time when they are easily broken off, it is important that the produce exploited should be cut up at once. Moreover, the small branches should not be left scattered about everywhere over the ground. It is often difficult, from want of sufficient hands, to cut up all the produce before the appearance of the shoots; but it is at least possible to collect the small branches on blanks or in badly stocked places. By this means the damage done is localized, and it is repaired whenever required with the aid of a little planting. It is also advantageous to extract dead stools, and put in a few transplants in their place.

The removal or carrying out of produce can only influence coppice growth by the damage which results from the passing through of carts and from the browsing of cattle. The extent of such damage may be considerable in the absence of proper supervision. But it can be lessened by having the produce collected along clearance routes fixed beforehand, or better still, when that is possible, by having

it carried out as it is cut up, and collected along some permanent road or at a depôt.

In spite of the damage which results from the cutting up and carrying out of produce, it must always be borne in mind that every limiting condition imposed on the purchaser of standing timber results in a depreciation of value. This depreciation is often made much of by intending purchasers, and hence only such precautions ought to be taken as are indispensable to secure the well-being of the coppice. The printed conditions of agreement for the purchase of standing timber* lay down the general rules carried out in the forests administered by the Forest Department, and provide for any departure therefrom by means of special clauses, whenever the circumstances of the case require them.

Reservation of Standards.—We have seen that standards in simple coppice are intended to be reserved for not more than two rotations of the underwood. Their principal object is to shed a few seeds, so as to keep the underwood fully stocked and at the same time to furnish a few scantlings suited for building purposes. From this latter point of view, whenever the soil is moist and rich, it is not unimportant to associate with the oaks a certain quantity of aspen and birch trees, which grow rapidly and yield wood which is in fair demand for various purposes. As to the number of standards to reserve, it ought not to be large, though it is impossible to lay down any precise rule on the subject. The reason for this is evident, since the moment it

* This is the well-known "Cahier des charges."

is determined to grow simple coppice, the most important produce sought is the underwood. Hence this latter ought to be overtopped as little as possible, and the rôle of the standards should be restricted to that of seed-bearers; otherwise it would be far better—and this is often true for all proprietors—not to mince matters, but to go in boldly for coppice with standards.

MAINTENANCE OPERATIONS.—In simple coppice these operations may consist in a little planting to fill up the blanks, which invariably occur here and there when there are no seed-bearers; and in cleanings, the object of which is to prevent the encroachment of the inferior trees. These cleanings have also for special object the liberation of saplings and transplants, which grow slowly at first, and cannot cope with the rapidly growing coppice shoots.

These operations are included in those which have to be performed in coppice with standards, and will be described in the next chapter.

APPLICATION OF SIMPLE COPPICE TREATMENT. COPPICE OF A SINGLE SPECIES.

THE OAKS.—The holm oak in Provence and Dauphiné, the Pyrenean oak in the country round Bayonne, the sessile-flowered and peduncled oaks in the centre of France and in the Ardennes, frequently form of themselves pure simple coppice. The first two are grown almost solely with a view to the production of bark, and the rotations are very short, ten to fifteen years. They scarcely yield 4s. 6d. per

acre per annum. It appears to us that something better could be done, especially for the Pyrenean oak.

In Sologne, and in the centre of France, the rotation is usually longer, from twenty to twenty-five years. The result is that besides good bark the two principal oaks also furnish wood of some value, and even poles that are used as small timber. When the peduncled oak is pure, the soil is much exposed, and coppice is kept up with comparative difficulty. Here also it is desirable to associate it with the hornbeam.

"SARTAGE" OR SURFACE FIRING.—In the Ardennes, the simple coppices of the sessile and peduncled oaks sometimes pure, sometimes associated, or growing with beech, hornbeam and hazel, are subjected to a peculiar process termed "*Sartage*"; that is to say, after the exploitation, the small branches and other refuse are burnt, and cereals are cultivated for one year. Such coppices are generally worked on a rotation of twenty-four years. The produce obtained consists of the cereal crop, bark, pit-props, charcoal, and fuel that is highly esteemed. All these various products yield together an average net annual revenue of about 9s. 7d. an acre. "*Sartage*" appears to have originated in the want of means of communication and in the poverty of the soil, which could not yield a regular succession of agricultural crops. With the present facilities for carriage, it has lost all its importance, and its continuance is only a matter of traditional custom doomed to die out in time and with the progress of industrial development in the

valley of the Meuse. "*Sartage*" is practised by firing either in the open air or in small heaps.

OPEN-AIR FIRING.—The first method is the better of the two, but it cannot be employed where the ground is covered with long grass. After the produce, which is exploited during the circulation of the sap, in order that the oak may be barked, has been cut up and removed, that is to say, towards August, the twigs and other refuse obtained from the exploitation are scattered as uniformly as possible over the surface of the ground. These are fired during calm weather. In order to prevent the fire from spreading into the adjacent portions, the precaution is taken of digging up the ground over a width of a few yards all round the area cut over, and the fire is controlled by men armed with long poles. Sometimes the ground is parcelled out into several small portions, which are burnt one by one. Some days after the firing, when it is possible to go to the spot, rye is sown broad-cast and covered by light hoeing.

This kind of firing can be employed on slopes as well as on plateaux. It offers many advantages: by means of the ashes it returns at once to those schistose slate soils, which are consequently cold and poor, a notable proportion of the inorganic elements that had been taken up by the forest during a whole rotation; it thus renders an agricultural crop possible, and the quality of these elements in excess of what is used up by the cereals, benefits the young forest growth for several years. The passage of the fire results in the destruction of the seeds of the

hurtful grasses; but it destroys at the same time the vegetable mould, as also the few acorns and young seedlings, which the coppice poles were able to produce. From the forester's point of view, the greatest advantage is to be found in the working up of the soil, by which it is loosened and earth collected round the stools. As these latter were cut down to the very ground, they now find themselves below the surface of the soil, and the shoots which spring up have thus a solid base, and at the same time strike root directly.

After the cereal crop is gathered in, a remarkable phenomenon takes place. A vast quantity of broom makes its appearance, the seeds of which, from having been preserved underground, escaped the action of the fire. They grow rapidly, and are not long in forming with the oak shoots a dense thicket. If they are not extracted the very first year of their growth, it is a mistake to get rid of them wholesale all at once, because the oaks, being drawn up and still only of small girth, could not stand alone.

The presence of this broom is often more useful than injurious. It protects the shoots from the cold north wind, which has nothing to check it on the exposed plateaux of the Ardennes. Formerly a curtain of big trees used to be left around each cutting as a protection against the wind; but these curtains have been cut down, and have not been renewed. The result is that the coppice is in danger of disappearing altogether on the higher points. Some of these places have been planted up with the Scotch pine and the spruce fir. Their

beneficial influence is felt at a great distance, owing to the plateaux being almost perfectly level. So far they have both done as well as possible, and it would perhaps be advisable to raise a continuous curtain of these trees along the line of water-shed.

FIRING IN HEAPS.—When the ground is covered with long grass, the open-air method loses all its advantages, for the fire burns only the stalks, without reaching the root. The cultivation of the soil hence becomes impossible, and a crop of rye would moreover be choked up by the grass which the ashes would cause to grow up with increased vigour. In this case the grassy surface ought to be cut up into sods and the adhering earth shaken off. The sods, together with the twigs and everything unsuited for charcoal making, are collected in heaps and fired, and the ashes scattered over the ground. Rye is then sown broad-cast and covered over as described above.

This method offers the advantage of rendering possible the reservation of a few standards, but it is greatly inferior to the other. Thus the upper portion of the soil, viz., that which is richest in mould, is removed; if the ground has a pronounced slope, the washing down of the soil is favoured; when scattering the ashes, there are always sods of turf, the combustion of which has been incomplete, and experience has shown that every stool, on which such sods fall, dies without producing a single shoot; lastly the stools are for the most part left slightly higher than the ground.

On the whole it is questionable whether surface

firing is really beneficial to forest growth. The advantage, about which there is least doubt, results from the working up of the soil. But though vegetation is favoured during the first few years by the action of the ashes, it is probable that it would gain at least as much by the slow but gradual decay of the dead leaves. Besides this, the practice of firing necessitates the continuance of simple coppice, though it appears evident that coppice with standards, rightly carried out, would compensate, and even more than compensate, for the loss which would result from the suppression of the rye crop. The fact is that in the system of coppice with standards the rotation of the underwood would admit of being lengthened, the yield would hence be smaller in firewood but larger in pit-props, and the reserve would furnish useful timber for building and other purposes, and it is well known that the price of such timber is daily on the increase.

BEECH: "FURETAGE."—We have seen that the beech is perhaps of all trees, the one least adapted for simple coppice. Still there are about 100,000 acres of simple beech coppice, belonging for the most part to private proprietors. These coppices are situated chiefly in that part of France formerly known as Morvan, on the Swiss side of the Jura, and at the foot of the Pyrenees. There they are frequently subjected to a peculiar treatment called "*furetage.*" (In some countries coppices of oak, or of several kinds of trees growing together, are similarly worked on this plan.)

"*Furetage*" consists in cutting the strongest

shoots out of a clump and in leaving the weaker ones. The wood-cutter returns to the same place every eight or ten years, and if the poles are cut at the age of twenty-four or thirty years (*i.e.* if the rotation is of twenty-four or thirty years), the clumps are composed of shoots of three different ages. Here we have the selection method applied to coppice. The coppices treated thus are usually simple without any reserves. They are little known, and have perhaps not been sufficiently studied. Nevertheless it does not appear to us that "*furetage*" should be generally adopted, because in the first place, it seems preferable to grow the beech as high forest, and, for private proprietors who possess forests of this tree, as coppice with standards. If the standards are cut early enough they will not injure the underwood they overtop, especially if the rotation is sufficiently long, and they will be able to shed seed, by which the growing stock will be kept full. Moreover, although "*furetage*" has hitherto preserved beech coppices in a more or less satisfactory condition, it presents many disadvantages. Thus it is exceedingly difficult to cut a certain number of the shoots in a clump without injuring the rest; in any case the labour required is more costly. Besides this, cutting up the wood is not so easy when the shoots left standing are to be preserved from injury, and it is necessary either to remove the former on men's backs or allow carts to come in among the standing crop,—a circumstance which is necessarily productive of damage.

THE SWEET CHESTNUT.—The sweet chestnut is

not indigenous to France. When allowed to grow to an advanced age, it becomes rotten in the centre and produces a scanty outturn owing to waste. When it is cut young, on the contrary, its wood is sound and durable; it is in great demand for vine props, and returns large profits to the grower. It is therefore important to study how to raise and work a plantation of this species.

It is first of all necessary to bear in mind that the sweet chestnut absolutely refuses to grow on calcareous soils. The soil which suits it best is one that is gravelly and silicious, like that which results from the decomposition of granite. It succumbs to late frosts on southern and western slopes, and strongly objects to the presence of grass. Its growth is very rapid; and it coppices and throws up suckers freely.

In making a plantation of sweet chestnut, it is advisable to begin by putting the ground under agricultural crops for two or three years, giving the preference to crops which require weeding, such as the potato for instance. The soil is thus completely freed of injurious herbage, and is now fit to receive the transplants which have been previously raised in a nursery. These are put out six feet apart in every direction, and in the intervening space the potato may be cultivated for another year or two. At the end of six or eight years a preliminary cutting is made, the yield of which just covers all expenses. After this the plantation is worked as simple coppice without reserves on a rotation of ten, twelve, or fifteen years. A sufficiently good indication of the

age at which the shoots should be cut is furnished by the appearance of suckers near their base. A chestnut plantation lasts in this manner for about a century and a half, after which it is time to renew it. When situated near vineyards in favourable conditions as to soil and aspect, a chestnut plantation returns very large profits, and is appropriately placed in the hands of private owners.

THE ALDER.—The alder also is well suited for simple coppice. It is a tree that coppices very freely and for a long time. It is invaluable for rendering wet lands productive. It is rarely found associated with other kinds, both on account of the soils it affects and of its very rapid growth. The rotation to apply is longer or shorter, according to the nature of the produce demanded, and varies from twenty to twenty-five years. There may be advantage in leaving a few reserves in order to obtain larger poles, which are in demand as conduit pipes for fountains.

SIMPLE COPPICE OF MORE THAN ONE SPECIES.—The species which are most frequently associated together are the two chief oaks, the hornbeam, birch, aspen, ash and beech. When the mixture exists in due proportions, it is highly advantageous on account of the variety of the produce obtained, and the improvement which results from the soil being more completely covered and richer in vegetable mould. But supervision is necessary, and cleanings must be made with the object of setting free the few seedlings which may come up and of preventing the shoots of the hard woods from being over-topped by

those of the soft woods. The rotation to apply will depend on what is the most valuable species in the coppice and on the kind of produce required. But it is right to remark that the shorter the rotations are, the more favourable will be the conditions for trees of rapid growth, which are frequently of inferior quality.

CHAPTER II.

COPPICE WITH STANDARDS.

GENERALITIES.—In growing coppice with standards, the end in view is to combine at once the advantages of simple coppice and some of those of high forest. In other words, to a ready and certain reproduction, since it is obtained principally by means of stool shoots, is joined the production of a special quality of timber. This mode of treatment therefore contains two elements, the underwood and the reserve, which are incompatible to a certain extent with each other, but can, notwithstanding, be sufficiently reconciled together. The repeated cutting of the underwood periodically isolates the standards, which gives room for the production of epicormic branches. The standards are low, because, being selected from among the coppice poles, they do not gain in length of bole after they are isolated. Lastly the soil, exposed

regularly at rather short intervals, is not in a position to improve. On the other hand the standards always act more or less injuriously on the underwood which they overtop.

ROTATION.—Choice of length of rotation gives us an opportunity of lessening the evil effects of the frequent cutting of the underwood. It is evident that the more we approach the superior limit of forty years, the more will the soil be covered, the higher will be the underwood, and consequently the standard boles, and the less we shall have to fear the development of epicormic branches. Indeed it is obvious that the rotation ought to be longer than what would suit simple coppice placed in the same condition of soil, climate, and species. For in coppice with standards, the underwood possesses, for the most part, only a secondary importance in comparison with the reserve. It is the latter, therefore, which ought to be encouraged, and the best means to that end consists in lengthening the rotation.

The rotation for the underwood being determined, the age at which the standards must be cut is a multiple of it; but this multiple is not the same for all proprietors or for all trees. Thus the State and Communes are interested in letting their standards, grow to an old age, whereas the private proprietor will always seek the most advantageous investment for his money (and therefore cut his standards younger). Similarly the oak ought to be cut later than the beech, &c.

The reserve is divided into as many classes as

there are different ages of standards. They may be thus termed :—Standards of the

1st class, or 1st class reserves, those of one rotation.
2nd ,, 2nd ,, ,, two ,,
3rd ,, 3rd ,, ,, three ,,
4th ,, 4th ,, ,, four ,,
Old reserves or standards (veterans), those which count five or more rotations.

With respect to the action of cover exercised by the reserve, it is provided against, as far as possible, by the choice and the number of the standards. Lastly it is necessary to pay attention to the distribution of the standards in the interest of the good vegetation of the reserve itself.

CHOICE OF STANDARDS.—In the selection of standards, account must be taken of their origin, the species to which they belong, and their shape.

By origin is to be understood whether they are derived from seedlings (tellers) or from shoots and suckers. Theoretically seedlings alone ought to form the reserve : they are longer lived. Although at the beginning they grow much less rapidly than shoots, they are not long in overtaking them, and, after fifty or sixty years, they go ahead and reach the largest dimensions that the species to which they belong can attain. Their foot is always sound. On the other hand, the shoot which has sprung up on a thick stool has a misshapen foot, rotten to a greater or less height, sometimes as much as six feet. This arises from the fact that, as the shoot increases in girth, it gradually grows round the stool which has already begun to rot. This decay

spreads from below upwards, slowly it is true, but surely. If such a pole is selected as a standard and is allowed to live to a great age, the most useful portion of the tree is thus lost, *viz.*, that with the largest girth and volume.

But this is not always the case. When the shoot stands on a little stool, like that which is derived from a seedling copsed down at an age not greater than that of the underwood, it englobes the stool while the latter is still sound. The stool, protected from weather influences, is no longer liable to rot, and the shoot has all the value of a seedling.*

It is these shoots on young stools which form the finest and the most numerous standards. For it is seldom that trees derived directly from seed can be preserved; owing to their slower growth they always remain under cover and are hence defective in form and too weak to be isolated with advantage. It is only when they have been copsed down that they can hold their own with the surrounding coppice and shoot up vigorously.

Since it is necessary to exclude coppice shoots from the reserve, it is also necessary to be able to distinguish them. This is no difficult matter when they form a clump on the same stool. But individual shoots also are found. When they have not sprung from small stools, and it is only in this case that there is advantage in recognising them, they always exhibit, on the side of their insertion, the trace of the bend which they describe in gradually taking a vertical growth after having burst through the bark.

* For convenience we will term these also tellers.

On the other side there is a flattening out of the foot, which contains the whole or a portion of the englobed stool.

As for suckers, they have a better future before them than stool shoots, inasmuch as they have their own roots and are therefore independent. But the species which throw up suckers are not generally those which it is expedient to reserve.

The choice of standards is regulated by species, insomuch as only those ought to be reserved from which we can expect useful timber. This is tantamount to saying that the oak is the most valuable of all species, and what is more, its very light cover causes little injury to the underwood. After the oak, for the same reasons, preference is to be given to the ash, the common elm and the two large maples (*A. platanoides* and *A. pseudoplatanus*). The beech and hornbeam only come in the second place especially on account of the facility with which they reproduce themselves by seed in the underwood. But it is necessary to preserve a few trees of these species, because the beech does not copse as well as other kinds, and the hornbeam, though it throws up abundant shoots and that to an advanced age, has a light seed which ripens nearly every year, and therefore makes it useful for filling up blanks. But only a few are wanted, and these ought not generally to be preserved for more than a few rotations. These two species possess a very thick cover, which destroys everything underneath, when the trees are old. They do not gain perceptibly in quality by growing isolated; and sufficient timber is obtained from them

in high forests. Lastly, just as in simple coppice, private proprietors may find it to their interest to reserve a certain number of aspen and birch when of good growth.

Only well-shaped standards must be selected, *i. e.*, those which combine with a sufficient length of bole a proportionate diameter and a well-developed crown. This latter quality, in the case of first class standards chosen from a complete canopy, can always be ascertained by an examination of the foot. A tree whose foot spreads out freely in every direction at the point where it enters the ground, is a vigorous tree.

First class standards ought to be selected exclusively from among straight trees. There is always a sufficiently large number which bend down after isolation to meet the demands of the dockyard in "knees;" this point requires attention only in the case of second and third class standards. It is also from among the latter that trees must be reserved possessing thick branches which will furnish curved timber for ship-building. But for this purpose the trunk and the branch must be in one and the same plane.

With respect to trees of which the trunk separates at no great height into two or three branches very nearly parallel, their reservation as standards is undesirable. They cannot as a rule resist violent winds, and in working them up, much wood is wasted, and there is no special use to which they can be put.

NUMBER OF STANDARDS.—On account of their

spare crowns and the fact that the action of cover is not felt equally over the whole horizontal surface of projection, it is admitted that the cover of first class reserves is not injurious. For this reason the question as to number of trees to be reserved can concern only the other classes, and especially those which have lived more than three rotations, the crowns of which are not only broader but a great deal deeper. Before calculating the extent of surface which ought to be covered by the reserve, even before inquiring into the circumstances which, in a general way, permit of the reservation of a greater or smaller number of standards, it is useful to have clear notions on the action of cover.

As we have seen in the definitions, the word cover expresses sometimes the horizontal projection of the crown of the tree, sometimes the action itself exerted by the crown on that area. This action is always injurious, because the direct rays of light are intercepted, the formation of dew prevented, and the equal distribution of rain rendered impossible. But in the first place cover does not always act with the same intensity, and in the second place its effect is not felt equally on the whole surface of projection of the crown. With equal areas, the intensity varies with the species, and for one and the same species with the thickness of the foliage and length of bole. When the bole is of sufficient length, the effect of cover may be rendered insignificant. We have a proof of this in the seedlings which come up and grow under a complete canopy of lofty trees.

It is therefore clear that the lighter the cover of

the standard is, the greater will be the number we may reserve without sensibly increasing the injurious effects. Similarly, if the underwood is of a kind to withstand the action of cover well, we can reserve more trees. The same may be done in rich soils and on moist aspects, because the vegetation being more active, there is greater length of bole.

A few years ago it was admitted, as a principle, that the standards ought not to occupy at the outside more than one-third of the wooded area at the time of cutting. This idea was conceived in Germany, where forests worked on the coppice system form the exception, and it was introduced into France about half-a-century ago. The great renown of German foresters caused their opinions to be accepted in France, unfortunately without a sufficient examination of the grounds on which they were founded. Yet, when rules for the treatment of coppice were being formulated in France, this examination ought to have been made, on account of the large extent of country in which the coppice system had been employed from time immemorial, and of the excellent results which it yielded. It will be interesting to inquire as to what could have led to such a belief, and to shew all the wisdom of the provisions of the Act, which—itself only the reproduction of the Statute of 1669—is bound to result in a numerous reserve.

Scarcely a century ago, means of communication did not exist in forest districts. Heavy timber especially could not be carried out. Besides this there still existed a large extent of forest; and build-

ing and other timber, for which the demand was far less than at the present day, possessed a relatively low value. On the other hand fire-wood was converted into charcoal, and found a steady market for metallurgic purposes. In any case in the state of charcoal, its transport cost little. Hence fire-wood formed the principal produce of coppice with standards, and it was necessary to impede as little as possible the growth of the underwood. We can now understand why only one-third of the wooded area was to be reserved for large trees, and the remaining two-thirds given up to coppice.

Circumstances have greatly changed in the last thirty years. At the present day, thanks to good roads, there is scarcely a single forest from which large timber may not be brought. Railways, development of manufactures, and general prosperity have increased the consumption of timber to an enormous extent, while its production has decreased. Moreover prices have more than doubled since then. On the other hand, the substitution of coke in metallurgy, has thrown out of the market a considerable portion of the wood which used to be made into charcoal. Leaving out the great centres of consumption the prices of firewood have in many instances fallen. The money value of a cutting in a coppice with standards now depends solely on the quantity of timber it contains, and even private proprietors are led by their own interests to pay more and more attention to the reserve. Thus the principle of limiting the reserve to a third of the wooded area has now become entirely inadmissible.

Besides in coppice forests under the management of the Forest Department, that principle could not be applied without infringing the provisions laid down in Article 70, of which it now remains to examine the great advantages and the few disadvantages.

Article 70 contains two paragraphs, of which the first relates to the number of first class standards to be reserved per hectare. This is not so important as the other paragraph, which runs thus: —"Standards of the second, third, and fourth classes shall not be felled unless they are decaying or are not in a condition to gain by being allowed to stand till the beginning of the next rotation." Thus, as long as they are still sound, or are not yet really mature, existing standards, to whatever species they belong, must be preserved; and as this rule can concern only long-lived species, the reserve must necessarily be very numerous and ultimately occupy the greater portion of the ground, with this condition, however, that their crowns remain free. The main object in growing coppice with standards is, in point of fact, to produce dense tough wood, especially oak, which full canopied high forest will never yield.

Thus it is easily comprehended that whenever the reserve is composed of oak, its number will be no real danger to the underwood, especially if the latter, while containing a little oak, consists principally of beech and hornbeam. The consequence may be that the coppice will be composed of scattered and weak stools, but then, under these numerous standards forming apparently a canopy of high

trees with long boles, seedlings will come up and maintain themselves till the next exploitation. These seedlings will then be cut back with the coppice, and wherever a standard has been felled will throw up vigorous shoots, which later on will furnish the best and finest standards.

Facts prove the truth of what precedes; in other words the theory is what it ought always to be, practical deductions drawn from phenomena observed in nature. As long as the Statute of 1669 was rigorously obeyed (up to the beginning of this century), the oak maintained itself most successfully in our coppices. The same may be said of those forests where, subsequently to that period, the spirit of the Statute was followed. It is only when few standards were preserved, that the oak has been observed to disappear, the natural sequence of cause and effect. If the underwood is but slightly covered by the reserve, it grows vigorously and never fails to choke up seedlings, of which not a single one will be found at the next felling.

In the case of Communal forests, Article 70, under the action of which they are placed by Article 134, has perhaps still greater importance, as it is the only legal restriction in the hands of forest officers to check the abusive enjoyment of usufruct by the present generation. But the second clause alone is applicable; the first is replaced by the terms of Article 137. This latter Article also contains two clauses, of which the second, respecting the allotment of one-fourth of the area to reserve, has given rise to claims (on the part of communes) the

groundlessness of which it is expedient to show. The Article runs thus:—"In cuttings made in forests belonging to communes and other public bodies, the number of standards laid down by Article 70 of the present Statute shall not be less than forty or greater than fifty per hectare, (fifteen or twenty per acre). When marking for reserves, in those portions of forest which are included in the reserved fourth of the whole area, the number of trees to be preserved per hectare, shall be not less than sixty and not greater than 100" (twenty four or forty per acre).

It has been argued from the word "tree," in the second paragraph, that the number fixed includes standards of all classes. Now in the first place Article 137 does not say so. It overrules only the first paragraph of Article 70, the only one which lays down the number of standards to be preserved. In the second place, by the expression "first class standards" is generally understood individuals of the same age as underwood that is worked on a rotation of the length usual in coppices. Now Article 140 provides that the portions which comprise the reserved fourth of the total area, ought not, as a general rule, to be cut except when in a decaying state, that is to say, when every individual has become a tree in the ordinary acceptation of the word. Being necessarily unable to foresee at what age cuttings would be made in each case, the word "tree" was employed, by which must be understood individuals of the same age as the underwood,

without any reference whatever to the reserve of the other classes fixed by the second paragraph of Article 70. It would besides be absurd to maintain that less solicitude has been shown for the reserved fourth of the total area than for the ordinary cuttings; and it would be just as reasonable to assert that because the first paragraph of Article 137 does not specify that first class standards alone are meant, therefore the number "not less than forty and not more than fifty" includes equally well all classes of standards. This contention has never been raised.

But Article 70 itself is not quite perfect, as it makes no distinction between the various species. If it is excellent, so far as the oak is concerned, it is not always so in the case of the beech, the hornbeam, &c., old trees of which possess a cover that is too thick for seedlings to maintain themselves underneath and which leave large gaps when cut, especially if the rotation is short. Nevertheless, while remaining within the strict letter of the law, these drawbacks can be overcome by means of the Special Provisions of a Working Plan, for Article 15 of the Forest Code lays down that "All woods and forests belonging to the State are to be worked according to working plans sanctioned by a special Act of the legislature." Article 90 contains provisions to the same effect for Communal forests. A working plan has hence the same force as the statute, and may overrule it.

From what precedes, the following conclusions

relative to the number of standards are legitimately drawn: —

1*st.*—The reserve ought to be numerous and composed chiefly of oak; it is the best means of securing a good future reserve and the maintenance of the oak.

2*nd.*—No thought need be given to the space occupied by the reserve, as long as the crowns of the trees are free.

3*rd.*—It is desirable to preserve as first class standards all healthy saplings and tellers of oak, ash, elm, &c., and to a certain extent of beech and hornbeam.

4*th.*—Oak, ash, elm, &c. ought not to be cut before they are really mature, unless they are too close together, or are in full decay.

5*th.*—Trees which are reserved with the sole object of keeping the underwood as full as possible, should be cut only after they are completely fertile, beech generally at the end of the third or fourth rotation, hornbeam at the end of the second.

If it were objected that such a forest is no longer "coppice *under* high forest" (*taillis sous futaie*), it would be easy to reply that it is at least "high forest *over* coppice" (*futaie sur taillis*), and that if this latter meets better the actual requirements of the country, and is more in consonance with the wants of the future, it ought to be preferred. Besides this there is unfortunately no danger, as long as the reserve consists chiefly of oak, of its being numerous enough to become hurtful.

DISTRIBUTION OF THE STANDARDS.—There are few remarks to make on this subject, because in the majority of cases we must be guided by circumstances. If it is necessary to reserve all seedlings and vigorous oak shoots on young stools, reserve them by all means, and once they become second class standards, their condition of growth alone will decide whether they ought to be felled immediately or spared for another rotation. Only it must be observed that there is no advantage in preserving a young oak standard under another which is capable of living through several rotations; in this case it is better to cut it down and ensure the existence of a young clump. When the different classes of standards are of mixed species, it would be an error to preserve a second or third class standard of beech, if it is perceived that before the next felling it must damage a fine oak standard of the first class; such procedure would be justified only if oak was very abundant and beech very rare, both in the reserve and in the coppice.

It has frequently been considered advisable not to preserve standards of the same class situated near to each other, especially when they belong to the third and fourth classes. Unless the standards are of beech, which, moreover, it is useless to allow to grow to a very old age, it is, on the contrary, advantageous to have several third and fourth class standards growing together in a clump. The reason is that these trees draw each other up and acquire a greater length of bole than if they were isolated. They therefore contain more useful timber, and under the

light cover of the oak, we are perfectly certain of finding seedlings, which will ensure a large supply of good material for the reserve, and the maintenance of the underwood without having recourse to artificial means.

But if there is no danger in preserving a clump of oaks, on the other hand it is decidedly wrong to reserve, under the pretext of avoiding large gaps in the forest and effecting an equal distribution of shade, a large number of first class standards of hornbeam, or of any other species, useless as timber. It is undoubtedly unfortunate to have portions without oak; but it is not the hornbeam standard that will bring back the oak. Such a standard will be fit only for fuel when it reaches the second class. Its preservation would prevent the formation of a stool of shoots which would yield at least as much produce as the standard, and would better promote the denseness of the underwood. As to the utility of distributing shade equally, it is very questionable when we have to deal with indigenous species adapted to the soil and reproducing themselves from the stool. Moreover it must not be forgotten that first class standards will at the end of the current rotation have become second class standards, and their cover will therefore have become injurious in proportion to the denseness of their foliage. In going through a forest of coppice with standards, it will be vain to look for oak under second class reserves of hornbeam, beech, &c., whereas that species will frequently be found growing under aspen and birch. Hence these latter ought not to be excluded

from the reserve where they are well grown; and this all the more on account of their being in great demand for certain purposes.

We have said enough to show that the operation of marking for reserves is a difficult one to do well, whether it be the selection of trees to be felled or those to be preserved as standards. Thus, while aiming at the formation of a numerous reserve, it must above all be remembered that it should be composed solely of really useful material. Except when converting coppice into high forest, it is a mistake to seek number for the sake of number. Besides the risk of creating dangerous cover, and of raising an obstacle to the maintenance of oak seedlings, bodily and mental fatigue is to be feared.

In marking a number of saplings for first class standards, one is apt to deceive himself into the belief that he has created a very extensive reserve, whereas it often turns out that only a few standards of the second class and two or three of the third class have been left per acre, and yet it is these last that constitute the main value of a coppice with standards. It is therefore necessary to give most attention to the existing reserve and to the intelligent execution of the second clause of Article 70. Without setting aside the first clause, it would be quite as puerile to lay claims to having reserved the prescribed number of trees when no attention whatever has been paid to the species to which they belong, as to stop short on the plea that the required number has been attained, relatively to the total area over which the

felling is to be made, when a quarter or a half of the whole surface still remains to be examined.

For the sake of despatch there is often a tendency to mark the trees to be reserved and to measure those to be felled, simultaneously one with the other.

This is a vicious practice, as it exposes the forester both to make a bad selection of reserves and an erroneous estimate of the quantity of produce to be cut. This last fault might, strictly speaking, become insignificant if there is an active competition among purchasers; but the effects of an injudicious selection of reserves are felt for several rotations. It is therefore necessary to execute this latter operation with the greatest possible care. When the estimation of the material to be cut is taken in hand separately, after the reserves have been marked, the forest officer is obliged to pass all the trees in review a second time, at least the oaks. He is thus often led to preserve standards of more than one rotation, which were either overlooked owing to an imperfect examination or forgotten in the pre-occupation of keeping the register correctly. No doubt this method requires a little more time, but it is only a question of a few minutes, and time spent in examining the forest is never time lost. It is thus that the execution of these operations becomes a labour of love, and the public no less than the proprietors cannot but gain by it.

ANNUAL YIELD.—As for simple coppice, so also for coppice with standards, and for the same reasons, the annual yield should be based on area. To the

objection that in this case the reserve furnishes important produce the yield of which should be steadily maintained and accurately determined, it may be answered that the same fluctuations would exist if the annual yield were based on volume, and moreover the length of the rotation would in that case be uncertain.

MAINTENANCE OPERATIONS.—As in high forest so in coppice, certain improvement operations are necessary, if it is to be kept at its highest pitch of production. These operations relate as well to the reserve as to the coppice. The latter ought to be cleaned and thinned, and may need a little planting; the former require to be pruned, using the term here in its general sense.

CLEANINGS.—Cleanings in coppice are intended to set free the tellers, and generally to encourage the more valuable species. Only let the rotation for the coppice be long enough (say thirty years), and it will be the exception not to find seedlings on the ground at the moment of cutting. Nay the number is frequently quite large enough not only to keep up the underwood, but also to ensure a plentiful supply of material for the future reserve. But although the seedlings have maintained themselves until the time for cutting arrives, they are not yet out of danger for all that. On the contrary, now is the most critical moment for them. The reason is clear. Coppice shoots grow much more rapidly at first; and, if during the first two or three years, the seedlings are not immediately overtopped, the cause is to be traced to the wide space between two successive stools.

But very soon the stool-clumps spread out and unite their crowns, forming a leaf-canopy, and the seedlings are inevitably destroyed under their low cover. It is therefore necessary to come to their aid, at the latest four or five years after the last cutting.

The time when cleanings should begin is easily determined, since reproduction is obtained at once by means of shoots. It is sufficient to find out how long oak seedlings can remain mixed up with the rest of the coppice without disappearing entirely or at least without beginning to wither. It is obvious that one single cleaning will even less fulfil its object here than in a high forest; it should therefore be repeated every four or five years until the fifteenth or twentieth year of the coppice.

In these cleaning operations, while aiming at setting seedlings free, the saving of every one of them is not for a moment to be thought of, when their number is very large. It will be quite enough to uncover a few everywhere, where there is any chance of their preservation. The first cleaning must consist in cutting the overhanging plants down to the ground; in subsequent operations of this nature, it is better only to cut them just below the level of the seedlings. By keeping up a continuous mass of foliage below, the disengaged seedlings are drawn up and natural pruning is favoured.

The first cleanings will yield no marketable produce. That is a strong reason for getting them executed by the forest guards, among whose duties this will be one of the most important. More than this, the guards alone are in a position to do them

well, and they must be compelled to give their closest attention to the work. Besides there is a way to make them take an interest in the work. The operations performed by these men, and notably the filling up of blanks, ought to be rewarded pecuniarily: why not regard cleaning as coming under the latter head, since it does away with the necessity of resorting to that operation? No one has an adequate conception of the good that a guard may effect within his beat. Supposing that only one day in the week, while inspecting his beat, he visits the young crops, bill-hook or pruning-knife in hand, and that he sets free only 100 seedlings; at the end of the year, that represents 5,000 plants, that is to say the equivalent of three to five acres of blanks successfully re-stocked. But it is not only once a week that the guard can do this work, he can do it nearly every day; and the total number of young oaks which an intelligent, hardworking man can set free and save, cannot be put down at less than 10,000 a year. Supposing only one tenth of these oaks is utilised for the reserve, what a mine of wealth have we not there for the future!

The yield of these cleanings should be based on area because their date is absolutely known; in other words they should be made in the same order as the coppice cuttings, and each operation should embrace one or more entire coppice areas. The same remarks hold good for the thinnings, of which we will now treat.

THINNINGS.—The good work that cleanings have begun for the seedlings, thinnings ought to continue,

if not always with a view to turning them into first class standards (for there are sure to be many below the level of the stool shoots), at least with the object of keeping them alive and sufficiently vigorous until the next cutting of the underwood. They will then furnish those shoots on young stools already alluded to above, when treating of the selection of standards. But the usefulness of thinnings does not end here. That there may be seedlings to set free in the cleaning operations, it is essential that they should be there before the coppice is cut, and it is their appearance on the ground that thinnings should endeavour to effect. These two operations are therefore complementary one of the other. Logically we ought to have treated first of thinnings, but it appeared preferable to take the several operations in the order in which they follow each other, starting from the principal cutting.

When the rotation of the coppice does not exceed thirty years, only one thinning is made; two may be made when it is as long as forty years. But before the age of twenty-five years, leaving out exceptionally fertile soils where the pole-stage is soon reached, thinnings are very difficult in execution and consequently attended with risks.

To facilitate the appearance of seedlings and to ensure their maintenance afterwards, the thinnings, or the last thinning when two are made, ought to remove all completely suppressed trees which immediately overspread the ground, and to raise the cover as much as possible without destroying the leaf-canopy. Breaking up this canopy would be still

more fatal here than in high forests, since the rotations are shorter, and independently of that, the soil remains only too long exposed after each exploitation. For this reason, the thinning must consist solely in pruning some of the poles and in extracting a few shoots. In a clump of shoots, only the strongest grow up vertically, as there is nothing to keep them down. The weaker shoots are more or less suppressed; they grow only in the direction whence light can reach them, and thus become more and more inclined, until they trail along the ground (trailers). It is these trailers which injure seedlings most, since they more immediately overhang them, and they must be got rid of by the thinning.

There may be some advantage in giving wider space to the strong shoots to allow them to gain in diameter; but it must not be forgotten that in a well-grown coppice with standards, containing therefore a numerous reserve, the underwood has quite a secondary importance, so far as forest produce is concerned. The thinning ought not therefore to overreach the object in view, viz., the production of seedlings and the setting free of saplings. It is only in simple coppice that it might more particularly aim at favouring the growth of the finer poles in order to obtain something better than mere firewood.

We are often recommended to preserve trailers in the hope that, being in contact with the soil, they may take root and form new stools. Without denying that such a result is possible, it may be observed that it is exceedingly difficult to cut any-

thing out of the straight portion of the clump without hurting the trailers; and in order to avoid this, it would be necessary to cut at some height from the ground. Moreover, they are seldom produced, except on stools of hornbeam, which copses freely, retains this power till an advanced age, and whose maintenance in the underwood is still further assured by frequent and abundant seedings. There is therefore very little advantage to be gained by their reservation.

PLANTING OPERATIONS.—If the cleanings and thinnings, which we have just discussed, have been carefully made, there is little occasion for planting. Still in the actual state of our forests, the generally small number of standards left in our coppices has gradually resulted in a decrease in the number of oaks. Nay, sometimes the proportion of this species in the reserve is entirely insufficient, and the underwood is too low and close to permit one to expect an adequate number of oak seedlings. Hence arises the necessity of introducing the oak artificially.

To this end many methods have been suggested. Although we have not yet taken in hand the subject of artificial restocking, it is easily seen that we are here concerned only with planting. Sowing is impracticable except when the area to be restocked is large; otherwise the seedlings, which germinate, would inevitably be suppressed.

Hartig directs that after the coppice is cut, twenty large seedlings per acre should be planted, so as to give them a start over the coppice. This method is defective from many points of view. As will be seen

later on, the success of transplants is the less certain the older they are; for a certain number of roots are always broken off in extracting them from the nursery lines, in transporting them to the place to be planted, and in putting them into the ground. To take the case in question, even admitting the success of the operation, some time must elapse before equilibrium between the crown and roots is re-established. By that time the transplants will be caught up and outstripped by the coppice, and the advantage of using odd plants will be lost. On the other hand, old transplants are costly, and they often require nurses, which swell the expenditure still more.

Another method, which has yielded excellent results, consists in loosening the soil, after the coppice is cut, along straight lines which intersect each other. By this disposition of the lines, the discovery of a single line leads to the discovery of the rest, and the transplants therefore receive all the care necessary. The transplants used are of medium size, they are put in at intervals of three to six feet, and are immediately cut back, an operation by which equilibrium between the roots and crown is established the very first year. By frequent thinnings, which are facilitated by the regular disposition of the lines, the coppice is prevented from crowding against the transplants. In spite of the excellent results obtained, this method is to be recommended just as little as the first: the number of plants used, the cultivation of the soil along the lines, and repeated thinnings, render it costly, and

it overreaches the end in view of preparing good and sufficient material for the reserve.

Another suggestion is to select blanks or poorly stocked places, loosen the soil in spots nine to twelve feet wide in every direction, and put a certain number of young transplants in each. These spots are difficult to find afterwards, and therefore to look after; moreover, of all the transplants crowded together in each spot, only one is likely to prove useful.

The defect common to these several methods results from their being practicable only after the coppice is cut, that is to say, when the new stool crop has already made its appearance. This is a circumstance eminently unfavourable to transplants, whose growth is already forcibly retarded by the mere removal from the nursery bed. We must therefore seek to carry out the planting before the coppice is cut. For several years past the planting out of young seedlings at the time the crop is thinned has been attended with marked success. The transplants are put out as regularly as possible, but especially on blanks, under high cover or under reserves which will be removed at the next felling. As coppice grows with difficulty under cover, the transplants are not cut back at once. During the few years which still remains before the rotation closes, they scarcely make any growth; but they establish themselves in the soil, and are only cut back along with the coppice. They are then quite strong enough to throw off one or two shoots, which make their appearance simultaneously with the young coppice

and grow more rapidly than a true seedling, and are easy to recognize and set free in the cleaning operations. Moreover, to facilitate their recognition, a stake, or simply the portions cut back, could be fixed in the ground near them. The cost of planting can be made as small as one could wish, and the results obtained are very satisfactory. This method is the one to be employed also in high forests to reintroduce the oak at the moment the close primary cutting is made; only, in this case, the transplants will, or will not, be cut back according to the amount of cover overhead, and the quality of the plants.

PRUNING OF THE STANDARDS. Under this general heading, it is necessary to distinguish two operations.

1. Ridding the boles of trees of the branches which grow on them as soon as they are isolated (epicormic branches). This we will specially designate pruning.

2. Lopping off certain branches belonging to the crown. This may be termed lopping.

The pruning of oaks is always useful, and in no case can it be neglected without danger. We have already referred to it in speaking of the oak reserves in high forest left after the final cutting. If these epicormic branches are allowed to grow on, they absorb, at the expense of the crown above, part of the sap which ought to reach it. They do not increase the quantity of the tree's foliage, but only transfer a portion to the bole, so that the tree soon becomes stag-headed and sickly. People are hence tempted to attribute this to a natural and premature decay. Instead of seeking the cause in the

existence of these branches, they fancy that the soil is no longer able to support old trees. It is too easily forgotten that the old reserves have passed through identical circumstances; and if no traces of this are now visible, it is solely because the up-growth of the coppice has stamped out the epicormic branches and enabled the trees to reform their crowns.

It is certain that during this crisis an appreciable number of trees die, and those which survive often contain an unsound heart-wood. The reason is obvious; after a certain time, the dry branches in the crown break off; the jagged section left behind decays, absorbs moisture, and allows water to penetrate into the interior of the tree. Thus may be explained in most cases the fact that coppice standards furnish a larger proportion of unsound timber than trees grown in the canopied blocks of high forest. But this defect can in most cases be obviated.

The means lies in getting rid of the epicormic branches as soon as they show themselves, or two years after at the latest. This should be done with sharp instruments, the bill-hook or the pruning-bill, cutting upwards to avoid tearing off any bark, and making the section on a level with the bole. At the same time some precautions are necessary; above all the use of climbing-irons should be interdicted. Each wound that penetrates as far as the sapwood is the inevitable cause of a fault in the wood. The wounded portion dies; sap or rain water collects round it, and decomposition sets in, giving the wood a blackish colour. The least that can

result is a solution of continuity, which renders the wood unfit for cask staves. Often the bark bears perpetual marks of these climbing-irons. The healed wound appears as a shorter or longer slit, on each side of which the bark, after meeting, swells up very much in the same way as in a covered diametral fault.

It is to dispense with climbing-irons that pruning-hooks fixed at the end of poles six to ten feet long are employed with advantage. If a sufficient height cannot be reached with this instrument, the best thing to do is to use a light ladder, which can be carried about easily from tree to tree and which leaves both hands free.

If pruning has been too long delayed, and the epicormic branches have acquired a diameter of two inches, it is often more expedient to let them alone or to cut down the tree if it holds out no further promise; otherwise numerous and large wounds would inevitably be occasioned in the bole of the tree, and new faults in the wood would be added to those which have perhaps already been caused by the infiltration of water through the dead branches in the crown.

It usually happens that after epicormic branches have been got rid of, others are produced. There must be no hesitation in pruning these off too. But they will be weaker and less numerous than the first; and if the operation has been properly performed, there is very seldom any necessity for repeating it a third time.

As to the best time for pruning, since it is above

all necessary to avoid everything that will favour the reproduction of these branches, which are veritable shoots, the most suitable season appears to be from the middle of summer up to the first frost. But scarcity of labour may necessitate cutting them in any season of the year, and provided this is is well done, no unfavourable results seem to follow.

The lopping off of branches in the crown is always a delicate operation, and has given rise to opinions diametrically opposed to each other. In order to be able to judge fairly, it is necessary to distinguish between lopping off dead branches and those which are still alive.

As a consequence of the isolation of a tree, it is exceedingly rare not to find some dead branches in the crown. If these are mere twigs and small branches, there is nothing to be done; they will fall of themselves; the broken section will soon be covered over, and will not give rise to any fault in the wood. Such is not the case when a secondary branch dies. A considerable number of years must pass before it breaks off and the wound is grown over. Indeed sometimes the wound will never heal up, and will allow water to enter and filter through down to the trunk of the tree, bringing decay with it. It is thus that rot in the foot of a tree, or a stain caused by infiltration of water, can, by making continuous sections, be nearly always traced to a former dead branch. It is therefore of the highest importance to look for all such dead branches and cut them off at their insertion on the principal branch. In this way the wound is allowed to heal up, and unsound-

ness in the wood, which is now no longer in contact with the air, spreads very slowly; in a word, becomes localised.

Dead branches which spring directly on the trunk at the lowest point of the crown must also be lopped off clean along the surface of insertion. However, before doing this it is advisable to study well the local and special conditions of vegetation. If the branch is erect and the wood liable to rapid decay, it must be cut off clean on the bole. But when the branch is horizontal or describes a small angle with the horizon, and is itself rather large, and especially if the oak tree in question contains tough timber not easily liable to rot, it is often objectionable to cut it off down to its point of insertion. By doing so, a large wound is uselessly made, and a solution of continuity is caused in the bole, when a little dead, but perfectly sound wood, would have been the only result. In this case it is quite enough to replace the jagged surface at the broken end by a clean section made at some distance from the trunk, whenever this can be done.

A live branch may be lopped off with the object either of increasing the length of bole, or of keeping a cover, that is too spreading, within proper limits, or of anticipating the mischief which would result from an accident.

It cannot be denied that length of bole is a very important quality; but we must not be guided by appearances. A tree, whose branches have been lopped in this manner, may appear quite sound so long as it is standing. Unfortunately our hopes are

only too often proved groundless when the tree is cut up. Not only does each branch lopped off give rise to solution of continuity, but it is very rare to find a wound covered over before decay has set in. Decomposition may then make very slow progress, but it never ceases. Wounds covered over fifteen or twenty years ago nearly always conceal hollows underneath, and often the mischief is propagated downwards, so that the length of bole artificially obtained is worthless if it has not even rendered valueless the rest of the bole. From this the necessary conclusion is that no live branch of more than one to two inches in diameter should be lopped off from standards of the second and higher classes, because at the time of felling there is sure to be a fault of a more or less grave character in the very heart of the wood.

It must not be forgotten that in a living tree every portion of the wood, which is exposed, necessarily dies. The wound may heal up more or less rapidly; decomposition to a less or greater extent may previously set in; but there can never be any coherence between the dead portion of the wood and the subsequent rings which cover it. The different substances, with which the section is sometimes coated, have only the effect of delaying decomposition; they cannot prevent the wood from dying. Little wounds, like those caused in pruning off epicormic branches or lopping off small branches in the crown, have little or no injurious effect. This no longer holds good in the case of the principal branches, the lopping off of which, close to the bole (the only mode of rapidly obtaining a covering of

new wood and bark), must cause large wounds. Thus it happens that wounds covered over in the most complete manner, always give rise, at the end of fifteen or twenty years, to decayed wood, and this chiefly towards the foot of the tree; for it is there that water accumulates after filtering through between the wounded surface and the new layers of wood.

This danger is very considerably diminished in the case of first class standards, because their branches are always small, and the wound caused by their being lopped off heals up in one or two years. Besides this, little is to be feared from such a wound, as it is quite close to the centre, a portion of the tree that is always cut out in important work. Here there is everything to gain by lengthening the bole. At the same time it must not be forgotten that these reserves have never too much foliage. Thus only those branches must be lopped off which are lowest in the crown and which have already begun to wither and would fall off naturally, if the leaf canopy were allowed to continue a few years longer. This is tantamount to saying that the length of bole can barely be increased by six feet; but that is something.

So far as the oak is concerned, its spare foliage can never cause much damage. More than this, an oak standard is worth more than the underwood it overtops. There is therefore no reason for depriving it of live branches in order to diminish its breadth of cover. Such a proceeding is always a mistake, since the sum of foliage cannot be reduced without

reducing the sum of production. At the most it may be allowable to cut off the ends of a branch which stretch out far and immediately overhang a first class standard of the same species; even then it is often more prudent to abstain from doing so.

In the last place, a live branch may be broken off by the wind or by an accident in the felling operations. In this case, the thing to be done is very simple. One of two cases happens. Either the branch still retains enough twigs to enable it to live, in which case its broken extremity must be lopped off close to the nearest twig, so that the section may be rapidly covered over, or else the branch is broken close to its point of insertion and cannot therefore live; here the same thing must be done as in the case of a dead branch, that is to say, it must be lopped off clean on a level with the trunk, if decay is to be feared or the branch is small; otherwise the broken surface must simply be replaced by a clean section.

It should be understood that the rules given above apply chiefly to the oak. They must be extended also to the elm and ash, large logs of which are in great demand, and which also suffer much from all kinds of amputation. As for the other species, they require less care, not because lopping does them no injury, but because they are much less valuable and may do real harm by their cover.

CHAPTER III.

APPLICATION OF THE PRINCIPLES OF COPPICE WITH STANDARDS TO MIXED FORESTS.

We seldom find coppice with standards composed of a single species; it is, on the contrary, advantageous to have a mixture of various kinds of trees. The species commonly met with are the two principal oaks, the hornbeam, beech, elm, ash, the service trees, the maples, the alder, lime, birch, aspen, and lastly willows and brushwood. It is obvious that according to the soil and climate, the mixture will contain a varying number of these species, in greatly varying proportions; but it is seldom that oak does not exist in considerable numbers.

Whenever oak is abundant, or can become abundant, and favourable conditions exist for its growth, the most important thing is to fix the rotation for the underwood because its duration has a great influence on the value of the reserve. A period of less than twenty-five years is not to be thought of; and in coppices where the term is shorter, there is everything to gain, even for private proprietors, by prolonging it to twenty-five years as a minimum. The interests of the community at large and consequently those of the State require that the rotation should approach as nearly as possible forty years in forests belonging to the State.

The rotation for the underwood once fixed, every proprietor should inquire at what age he ought to

fell the standards, private proprietors viewing the question from the stand-point of the ratio between revenue and capital, Communes and the State occupying themselves chiefly with revenue without reference to the capital which produces it, or more simply, with the usefulness of the produce. It is obvious that this inquiry concerns only the reserve as capable of furnishing timber, the interest of no proprietor ever leading him to grow to an advanced age trees which are reserved purely with the object of renewing the underwood with the aid of their seed.

In selecting trees for standards, a large proportion of oak should be reserved. To this end every healthy oak, to whatever class it belongs, should be preserved. Those only must be felled which are mature, too crowded, or in course of decay; a few dead branches in the crown, unless they are the principal branches, do not constitute a sufficient reason for rejecting a tree as a standard. A few branches may die, owing simply to the isolation of the tree, without however destroying its future promise. As for the trees of other species, greater latitude must be observed in giving them up to the axe, especially when they are too close to oaks which have not completed their full growth; but, with the exception of the hornbeam, they must, if possible, be maintained till they attain maturity. The hornbeam must be reserved only so far as its presence is required to keep up the underwood. If it is thought necessary to effect an equal distribution of shade, it is often better to reserve a few fine poles of aspen or birch, which will at least be

no obstacle to the maintenance of seedlings, and, in addition to this, will furnish produce of a special value.

The next operation which demands the utmost care is the actual cutting. All the stools must be cut down close to the ground, and particular attention must be paid that every existing natural and artificial oak seedling is cut back.

When the new crop is three, four, or five years old, according to the rapidity of growth, the time has come for making the first cleaning. This operation must be repeated at stated intervals up to the age of twenty years. Its object is not to liberate *all* the seedlings. It is seldom that these can be selected as standards at the next felling, but they can be kept in a sufficiently healthy state, that when cut back they may produce shoots fit to be reserved at the subsequent fellings.

According to the length of the rotation, the underwood should be thinned once or twice. This operation must continue the work of setting free the seedlings and effecting the germination of others. As the necessity arises, this end must be accelerated by putting out a few transplants five or six years before the coppice is cut.

It is obvious that without carrying out pruning to extreme lengths, the lower branches of first class standards may be lopped off, and epicormic branches carefully got rid of. If possible this latter operation should be executed the very year these branches make their appearance: the prompter the remedy, the more certain will be the result, and the smaller the cost.

The advantage of having a mixed coppice is self-evident, if a numerous reserve of oak has been formed and a fitting proportion between the various component species has been maintained by the aid of cleanings. At the same time that the underwood, so formed, contains a good future reserve, it is brought to its maximum of production. Any one who traverses such a coppice, will see healthy clumps of beech and hornbeam side by side with the old oaks. These clumps protect the soil, and shelter the boles of the oak, which thus yield timber of the first quality.

Note.—With the coppice system, may be connected the treatment of pollards and trees whose lower branches have been lopped off, leaving them only a small crown. But this cannot, properly speaking, form a department of sylviculture. The trees treated thus are always solitary, scattered in the midst of fields or grown along hedgerows. It must however be observed that besides yielding fodder, fuel, and wood for the manufacture of small objects, the trunks of these trees may sometimes serve the most important purposes. We obviously do not allude to the trunks of pollards, which are nearly always hollow, but with the other class of trees the case is very different. It is true they are full of knots ; but when the branches have been cut, and at frequently repeated intervals, and the wounds have healed up rapidly, it is not rare to find among oak trees subjected to this treatment logs of the very best quality. This explains why ship-builders esteem so highly trees which have grown along the

hedgerows in Brittany. If the knots are sound it is a proof of the strength of the timber, and the breaks in the continuity of the woody tissue do not prevent its being employed entire.

PART IV.

CONVERSION OF COPPICE INTO HIGH FOREST.

CHAPTER I.

HIGH FOREST AND COPPICE COMPARED.

To execute a conversion, signifies to change the method of reproduction; consequently in order to convert coppice into High Forest, its regeneration must be effected by seed, and that too in such a way as to obtain exploitable timber at the end of the operation. Indeed it is not enough to let coppice grow on in order to turn it into high forest, since the standing crop will be entirely the produce of stools, and conversion will still remain to be done.

But before undertaking an operation of this nature, it behoves us to inquire what are the resulting advantages. Without entering into details of political economy, which belong to the province of economic forestry, these advantages can still be rendered sufficiently intelligible.

It is beyond dispute that in the same interval of time, high forest furnishes a larger yield than coppice grown under the same conditions; yet it is

impossible to prove this rigorously, as it would be necessary to subject the same forest successively to these two separate systems. But observations tend to establish the truth of this proposition, which is besides an accepted fact among all foresters without exception.

Moreover, the produce of high forest has a wider range of usefulness. The quantity of large timber is more considerable, and volume for volume it contains a smaller proportion of unsound wood. However, the question at issue concerns only the range of usefulness, since coppice standards, as compared with high forest trees, yield timber which is denser, stronger, and composed of better nourished tissue on account of the unhampered development of their crowns. For this very reason their wood is to be preferred in important constructions. On the other hand, timber grown under close leaf-canopy is in great demand for manufactures. It should be noted too that high forests which have been thinned yield timber of medium density useful for almost all purposes, and lastly it must be remembered that the consumption of manufacturing timber is far more considerable than that of building timber. Thus the superiority of high forest over coppice is completely established.

So far as fuel is concerned, coppice wood is better than the old trees of a high forest. But on the other hand the underwood of a forest under coppice is very nearly counter-balanced by the produce obtained from the thinnings made in a high forest towards the middle of the rotation. Moreover, we

have already seen that the value of firewood has diminished instead of increasing.

Again, since high forest furnishes more considerable as well as more useful produce than coppice, it is evident that the revenue derived from it must be larger. But to obtain this larger revenue, it is necessary to accumulate a vast quantity of standing material, owing to which circumstance the ratio of revenue to capital engaged is small. This is equivalent to saying that those proprietors alone who do not consider their forests as a strictly pecuniary investment, are interested in growing high forests or in preserving those which they already possess, as such.

Lastly, a high forest, by the constant and complete manner in which it shelters the ground, ensures the improvement of the soil, and hence improved production in a higher degree than coppice. For still another reason, it can be shown that coppice is not so well adapted to improve the soil; it has been proved that the greater proportion of ash is found in young wood and in the outside layers of old trees; it therefore follows that repeated cutting of the underwood impoverishes the soil more than would be the case in high forest worked on a long rotation.

From all these different points of view, it is evident that the private proprietor has no interest in converting coppice into high forest; on the contrary, it would be to his advantage to realise at once the standing material of any high forest he may possess and turn it into coppice. If he is owner of a forest of conifers, which is from its nature

unsuited for coppice, he is always induced to limit the quantity of standing material to the lowest figure possible, and thus to adopt short rotations.

The State, on the contrary, has every interest in preserving its high forests and even in converting its woodlands under coppice into high forests. This is frequently a duty in face of the increased consumption of timber and the diminished area of its woodlands; only it must observe a certain moderation, and consult the timeliness of the operation.

As for Communes, while acknowledging that future generations would gain much by conversions, and that Communes, being perpetual proprietors, ought to be solicitous of the future, it should be remembered that the interests of the present generation ought not be overlooked, and that no sacrifice ought to be demanded of it from which it would be the only one not to profit. Increase of revenue necessarily implies previous savings, and there are few Communes sufficiently prosperous to create a budget surplus.

For Communes, then, the system of coppice with standards seems destined to remain for a long time to come the only method of treatment for their forests. Nor is the inferiority of this treatment to be exaggerated; when well applied it yields excellent results. The most important improvement which can be made in it, is without doubt a lengthening of the rotation and the formation of a numerous reserve, composed principally of oak. This constitutes a real saving, which, while being a rich source of profit, requires at first a very small sacrifice—a strong point

in its favour. If we only consider the enhanced value of a veteran oak, we see that the conservation of three or four more standards of the class immediately below may often double the value of an acre of coppice. Moreover, even as concerns rate of investment (ratio of net revenue to capital), it is sufficiently high, seeing that the price of large-sized timber is constantly rising.

The chief reason why coppice is inferior to high forest is to be found in the shortness of the rotation. A single act of recklessness in the oft recurring exploitations is enough to ruin a forest for several generations. The danger increases with the area cut every year. Certain forests there are, where the mischief caused by such operations carried on during a period of fifteen or twenty years, cannot now be repaired before the lapse of a century and a half. In a regularly worked high forest, on the other hand, when the rotation has been judiciously chosen and the blocks properly laid out, the damage caused by faulty operations is necessarily limited in area. Nothing short of the most careless thinnings can destroy the future of a crop, and regeneration cuttings must be very badly executed indeed for natural forces to be powerless to restock the ground with the valuable indigenous species, a certain amount of delay not exceeding a single period helping towards this end. But it is to be hoped that the progress of knowledge will continually decrease the frequency of operations executed at hazard or under a fixed idea. This leads us to recognise the necessity of first improving, without changing, the system actually

applied to any given forest. Later on when circumstances favourable to saving present themselves, the ultimate object in view should receive undivided attention, that is to say, conversions, now rendered easier by the improvement of the coppice, must be taken in hand. Considering the vast extent of woodland composed of coppice with standards, the impossibility of undertaking the conversion of the whole at once, and the fact that the operation of conversion itself requires the continuance of coppice in certain portions, this system will remain for a long time to come the principal mode of growing our forests. It cannot, therefore, be too carefully studied.

CHAPTER II.

EXAMPLE OF A CONVERSION AND THE CULTURAL OPERATIONS IT NECESSITATES.

It is beyond our scope, in a manual of sylviculture, to discuss all the combinations of economic forestry, by which a coppice is eventually converted into high forest. Still as the purely cultural operations are intimately connected with these combinations, it is necessary to pass them in review by taking an example representing the most general case.

Before proceeding further, it is necessary to lay down certain points, which may almost be regarded as axioms.

I. A conversion ought to be undertaken in the most economical spirit. Natural reproduction,

therefore, is the only method to be adopted. As reserves alone are capable of effecting this, it follows that immediate regeneration ought to be eschewed, unless the reserves are very numerous, and cover at least two-thirds of the surface of the ground.

II. Experience has clearly proved that it is absolutely impossible to turn to any account seedlings mixed with numerous coppice shoots, when the area operated on is large. This is the greatest difficulty of conversions. The only way to avoid it is not to begin regeneration before the underwood is too old to be able to produce strong and numerous shoots (fifty years at the least). The observance of this and the preceding conditions is of the utmost necessity.

III. As the underwood of a coppice is derived from stools and is often composed of inferior species, it is liable to die early. There is frequently no advantage in allowing such shoots to grow beyond the point of time when the stools lose their vitality.

IV. This last consideration and the necessity of not depriving the proprietor of nearly the totality of his income, lead to the gradual and successive conversion of the different parts of a working circle and the temporary continuance of coppice in those whose turn comes last.

V. If the coppice to be converted into high forest is simple, then it is better to begin by turning it into coppice with standards and at the same time lengthening the rotation.

VI. Similarly, if the coppice to be converted is poor in reserves, it is better to continue the old

system for a time, and to increase the reserve by leaving numerous standards.

These facts being assumed, let us suppose a coppice hitherto worked with a rotation of thirty-five years, and which is to be converted into high forest.

It is necessary first of all to determine the length of the regular (or normal) rotation to be applied to the future high forest, to divide it into periods and to define in the working circle an equal number of blocks. The object of this is to ascertain in what portion regeneration operations ought to be commenced, and therefore what portion should form what is termed the first Block. Suppose the rotation to be 180 years, and to be divided into five periods of thirty-six years each.

If the first Block contains a numerous reserve, and if, at the same time, the underwood is sufficiently old for the purpose, regeneration operations may be undertaken at once during the first period. During this interval, the Block which is to be regenerated during the second period, must be allowed to grow on, and only improvement operations, cleanings, and thinnings (usually termed cuttings preparatory to regeneration, or simply preparatory cuttings) must be made in it. The rest of the working circle must be treated as coppice with standards, cutting $\frac{1}{36}$ of the area annually. During the second period, cleanings and early thinnings should be made in the first Block, regeneration operations executed in the second, preparatory cuttings in the third, and copsing in the remaining two, and so

on. In this manner the conversion will be completed and the high forest regularly constituted by the end of the rotation of 180 years.

If, on the contrary, the first Block does not contain enough reserves, or if the underwood is still young enough to send up abundant shoots, the only proper remedy is to let the underwood grow on till it is old enough to bear seed. In this case the practice is to wait, usually for one period, before beginning the conversion proper. In the meanwhile preparatory cuttings are made in what is fixed upon as the first Block, and cuttings on the system of coppice with standards are continued in the rest of the working circle. At the expiration of this period, we enter the first period of the rotation, and must proceed as described above. In this way a regular high-forest will be constituted by the end of 180 years plus the period of waiting.

The advantages of proceeding thus or in any other similar manner are great and manifold: (i.) reproduction is obtained by means of self-sown seedlings; (ii.) shoots on stools are allowed the smallest chance possible; (iii.) we are not liable to be forced to keep standing for too long a time crops that hold out no promise; (iv.) a considerable revenue is steadily maintained during the whole interval occupied by the conversion, and it always tends to increase; (v.) a regular high forest is constituted within the shortest time possible; (vi.) and lastly, advantage can be taken of the coppice exploitations to improve the composition of the actual crops by an occasional resort to artificial means [sowing and planting].

To sum up, it has been observed that the cultural operations in conversions consist of regeneration cuttings, improvement cuttings (preparation for conversion), and provisional copsing.

REGENERATION CUTTINGS.—We have already seen, in discussing the treatment of high oak forests, that the first regeneration cutting ought to be made close. In the present case it ought even to be very close so as to oppose one more obstacle to the probable production of stool shoots. The best and largest quantity of seed will be furnished by the standards; these must, therefore, be all preserved, unless they are in full decay. They will seldom be numerous enough to insure the requisite amount of shade, and for this purpose it will be necessary to associate with them a certain number of the finest poles of the underwood. The isolation which the reserves have undergone produces a large development of crown, but on the other hand only a moderate length of bole. Hence it will often be necessary to lop off low branches, for the most part of beech and hornbeam. As these trees are to be felled at the latest in the final cutting, it is unnecessary to be over careful in this operation. But the case is different with oak. Those oak trees which are ripe for the axe may be pruned according to the directions given in a former chapter; as for the rest, no live branch is to suffer this mutilation. As a matter of course, it is necessary to clear away the low vegetation which may cover the ground and prevent the establishment of a crop of seedlings.

The secondary cutting ought to be made with

caution, and generally in two instalments. It should include all trees which exercise an injurious effect on the seedlings, be they the old standards or the poles spared from the last stool crops. Though lower, the cover of these poles may be less hurtful than that furnished by the dense and spreading crowns of old beech trees. On the other hand, the cover of an old oak is often less injurious than the less ample but lower cover of young beech and hornbeam. This cutting requires great prudence and *savoir-faire*. Moreover, it is necessary to guard against the development of shoots on the young stools; this may be done by being careful not to let in too much light. In spite of the primary cutting having been made close, some shoots may nevertheless have sprung up. These shoots must be cut back when a year of abundant seed presents itself; at the latest they must be cut back at the time of making the secondary cutting.

The final cutting should be made in the same manner as in high forests, that is to say, when the seedlings form a thicket and have nothing to fear from exposure to atmospheric influences. But here, even more than in actually existing high forests, there is every reason for reserving promising oak trees, for the reserve contains second class standards and young third class standards, which are still far from being fit to fall. These ought not to be cut except at the time of the successive coppice fellings, and besides this, their immediate exploitation would be little productive. Their number need not cause any anxiety, since only those which seem promising ought to be reserved, and such trees are but rarely

very numerous. Moreover, many must decay prematurely, and the seedlings as a whole will have little to fear from their reservation.

But there is another point to which it is proper to call the reader's attention. Those oak trees, which have grown in a state of isolation, and which, as they were to be preserved, were not pruned in the primary cutting, will have boles twenty to thirty feet long at the utmost. When the young crop is high enough to fill up the gaps between their crowns, and to form with them an unbroken leaf-canopy, the lower branches of these latter trees will necessarily die, and hence it may be feared that diseases and faults in the wood will be the consequence. But a little reflection will soon show that this danger is more imaginary than real. In the first place, so far as third class standards are concerned, it will generally be right to fell them at the moment this happens, for a considerable number of years will have elapsed since their preservation in the first regeneration cutting; and as for the second class standards it must not be forgotten that if they belong to a block where cuttings preparatory to regeneration have been made they will have lived in complete leaf-canopy during a space of sixty or seventy years. At the moment they are isolated, they will naturally possess boles long enough to have nothing to fear from being pressed round on every side by the new growth. The difficulty presents itself only when the regeneration of the first block is undertaken immediately, and never occurs afterwards.

It will lie with the executive officer to appreciate

the degree of promise held out by these second class standards; he will always remember that, if they can maintain themselves through only a single period they will be unquestionably much more useful than they actually are.

As the young crops are gradually uncovered by the final cuttings, nothing more is necessary than to carry out the improvement cuttings prescribed for high forests. Only there is occasion for still greater care in making the cleanings, in order to impede the development of stool shoots.

CUTTINGS PREPARATORY TO REGENERATION.—These cuttings are made in the block which is to be regenerated during the following period. Their object is to protect and assist seedlings of valuable species which may exist in the underwood, and poles which will be able to aid reproduction or be useful in creating sufficient shade. Unless they are in full decay, the old coppice standards should be preserved in the preparatory cuttings. The only way to contribute to the main end in view is to resort to a little branch-lopping.

We have thus in reality to execute improvement cuttings, at one time cleanings, at another time thinnings, according to the age and composition of the crops operated upon. But when they assume the character of thinnings they ought to follow the rules laid down for thinnings in a mixed crop, that is to say, they may include poles that overtop others, or are overtopped themselves, according as it is this or that species which it is expedient to reserve. These cuttings then are rather difficult to carry out,

and without breaking into the leaf-canopy, there must occasionally be no hesitation in freely extricating the crowns of oak trees. If there is a chance that these oaks will be good enough to reserve after the final cuttings, this operation will be a considerable step towards the goal.

To obtain from preparatory cuttings all their useful results, it is clearly necessary to repeat them periodically like thinnings. Taking into consideration the age of the crops operated upon, a periodicity of from ten to twelve years appears highly suitable. By this means the conditions will be easier for distinguishing what is hurtful from what is still useful, and the dangers resulting from an operation carried out in too timid or in too rash a spirit will be avoided. It will also furnish increased facilities for selecting the standards to be preserved.

COPSING.—Coppice cuttings are continued in the blocks which still have to wait more than one period to reach their turn of regeneration. In these cuttings the end to be kept in view ought to be the formation of a numerous reserve composed of the most capable subjects for seeding the ground at the desired moment, consequently in those blocks whose turn comes last, a large number of standards of the first and second classes must be preserved. But this is not a reason for felling third class standards before they are mature. In the first place such a step would be a loss as regards the utility of the produce, and in the second place it must be borne in mind that in all probability several successive coppice cuttings will be executed before the moment for

regeneration arrives, and that hence it is wise to distribute the produce among the different fellings, in order to avoid too great inequalities in the annual yield. Lastly, if a numerous reserve of young plants has been formed, the temporary preservation of a few standards of the third class cannot present any danger; when they are ripe for the axe, their extraction will not compromise reproduction. It must be clearly understood that the importance of preserving these old standards has been urged chiefly with reference to the species oak. As for beech it is more advantageous to preserve first and second class standards than old trees in these provisional coppice cuttings.

Hence it may be asserted:

(I.) that in marking for reserves, while preserving the largest number possible of first and second class standards, the nearer the period of regeneration is, the stronger reason there is for reserving old oak, even if they are just beginning to decay;

(II.) that if the young reserve is numerous in the blocks which stand last in the order of regeneration, of standards above the second class, only those which are still really unfit to cut ought to be preserved.

In these coppice cuttings it is necessary to be very careful not to omit the different accessory up-keep operations, notably the pruning of first class standards to add to their length of bole, and cutting off epicormic branches on oaks of all classes. Also advantage should be taken, if it is necessary, to plant out a few young oak, whether with the object of afterwards

utilising them in the formation of the reserve, or simply considering them as an integral part of the future reproduction according to the greater or less interval of time that must elapse until the regeneration is commenced.

In the portions of the forest in which copsing will continue, provisionally of course, to be the mode of felling, it is obvious that cleanings and thinnings cannot consistently be neglected. On the contrary, these operations acquire here a high importance. On them depends to a great extent the success of the conversion. Bearing in mind that oak cannot well be grown pure as high forest, one must also be careful to set free at the same time seedlings of the auxiliary species. The result will be a proper mixture of trees which grow naturally with the oak.

ANNUAL YIELD OF CONVERSIONS.—The cultural operations required in conversions bear a striking resemblance to those of high forest and coppice, and this fact is enough to show that the annual yield of the regeneration cuttings should be based on volume, while for the preparatory and provisional coppice cuttings, area should form the basis on which the annual yield is fixed.

To sum up: the different cultural operations required by a conversion, ought all to contribute in effecting it as economically as possible. Conformably with what has been already said in treating of high forests, the end in view ought not to be the formation of entirely uniform crops, nor to sacrifice for this uniformity trees whose preservation cannot

cause any real damage and which have everything to gain by being left standing. Perfect uniformity is besides undesirable. In the case of a portion of forest which forms an unbroken leaf-canopy, it is undoubtedly necessary to regenerate it, if the majority of the trees are ripe for felling; to let it stand any longer would be running the risk of seeing the timber going to decay. Hence the length of the rotation should be so determined as to escape this danger and to obtain timber of the size most generally in demand. But it will never be long enough to produce timber of the size required for certain special purposes. This demand must be met by means of trees selected from among the most vigorous and allowed to grow on for another period or two. Similarly, to obtain the largest sum of utility, those trees should be reserved which have not yet attained the minimum girth desired, and of which a few can perhaps live on to the end of the new rotation.

Thus understood, want of uniformity in a crop is desirable in every respect. The forest is really made to furnish the maximum of utility, and is all the finer for it. We become more strongly attached to it; we raise in it true monuments depending solely on natural forces, which we are not liable to see multiplied to an abusive extent. Taking even private forests, there is none in which the interest of the proprietor should not make him preserve a few large trees. Who has not seen a few large trees suffice to increase very sensibly the value of a cutting, which, without them, would never have found purchasers, or would have sold for a mere

song? Hence, without falling into exaggeration, we need not fear a certain want of uniformity in the crops, which, for all that, will not be the less regular.

PART V.

RULES FOR LOCATING CUTTINGS.

To locate a cutting means to mark out the limits within which a felling is to be made. It is not an indifferent matter where a cutting is located, for on the order observed in this operation depend to a certain extent the good condition and vegetation of the subsequent crops. The main point, however, is to protect all kinds of reserved trees against the dangerous action of winds. Thus the rules which form the subject of this chapter are applicable to all kinds of cuttings, whether in high forest or in coppice. These rules may be thus enunciated :—

(i.) In the same working circle the cuttings should succeed each other in their order of date, and have the most regular form possible.

(ii.) The cuttings ought to be so located that the produce of an area in course of exploitation will not have to be carried through portions recently cut.

(iii.) The cuttings ought to be located so as always to march against the direction of dangerous winds. For France this would, as a general rule, be from north-east to south-west.

(iv.) In hill forests the cuttings should begin at the bottom.

(v.) In hill forests, and in general where dangerous winds prevail, a cutting ought to be long and narrow in form, and have its longest side perpendicular to the direction of the winds.

These rules are not all of equal importance: the first two are universally applicable, the remaining three chiefly in mountainous districts, nor can they all be observed at one and the same time. In each case it is the duty of the forester first to appreciate local conditions, and then to apply that rule which he considers the most urgent, at the same time that he provides against the dangers which might follow from the non-observance of the rest. The reader will best judge of the relative utility of these rules by studying the reasons which have dictated them.

RULE I.—This rule is the most important of all, not only on account of the object it endeavours directly to attain, but because the application of the others is impossible without it. Taken by itself, it contributes in the first place to obtain the best vegetation possible, for it is manifestly better that two contiguous crops should be of nearly the same height; they enjoy thus all the advantages of an unbroken leaf-canopy, and the lower crop has nothing to fear from the immediate neighbourhood of the taller one. When the different cuttings follow each other in their order of date, the various crops which grow upon them, rise insensibly one above the other from the youngest to the oldest, without any one of them hampering the free growth of its neighbour. On

the contrary when the cuttings are not located in successive order, the younger crops get shut up, as it were, in the midst of the older crops, and thus suffer along their whole perimeter from the action of cover. The mischief is all the greater, as the perimeter of the cutting is more irregular, and therefore longer; for the width of the suffering belt remains constant. In the second place, it is easy to see that the damage caused to any part of the forest by operations in an adjacent portion where fellings are being made is less when the cuttings succeed each other in order, and have a regular form. Lastly it is the young crops which require the most careful watching both as regards their vegetation or the prevention of offences. This would be facilitated in an eminent degree, if they were grouped together, that is to say, if they followed each other in their order of date.

Notwithstanding the great advantages which follow from the observation of the first Rule, the actual condition of our forests does not always admit of its universal and strict application, at least in high forests. It seldom happens that the different crops succeed each other in order of their age. If we located our cuttings according to the letter of the first Rule we should be forced to introduce felling operations when they would be too early or too late, that is to say, we should sacrifice the present or the future without any compensating advantage. The wiser course is to aim constantly at regularity, without exposing ourselves to any great sacrifice. Provided the cuttings are located in regular order over a

sufficiently large area, 100 or 120 acres for instance, the greater part of the evil described above will be avoided, a result which ought to be considered quite satisfactory enough for the time being. Later on another step towards regularity may be made, and so on till a general regularity is attained; but in many forests it is hopeless to expect to arrive at this regularity in a single rotation only.

RULE II.—Amongst the many dangers to which young wood is subject, the most to be feared is that which results from the carrying of the produce of adjacent cuttings through it. Besides the damage necessarily caused by opening out new roads, the young crops are always in danger of being browsed upon, as long as they are not high enough to be out of the reach of the beasts of transport employed. The extent of this mischief can easily be imagined when we consider that the number of these roads must be large, since, being situated on the bare soil of the forest, they very soon become impracticable and that, in addition to this, the produce of several different cuttings is carried to the same point. Hence each cutting ought to have, so far as possible a separate system of transport roads; and the establishment of good roads is one of the greatest improvements that can be made in a forest. The evil we have referred to is still more to be dreaded in forests of conifers, for the damage done to young trees cannot be repaired by simply cutting them back, as those species do not grow from the stool.

When firewood alone is concerned, men might be employed to carry it out to certain places fixed be-

forehand, so as to restrict as much as possible the passage of carts through the young crops. This is obviously impossible in the case of large logs, the only alternative here is to transport them by the safest means that can be devised. On level or very gently sloping ground, limbers consisting of high wheels may be used with advantage. The log is suspended by its middle or rather its centre of gravity by means of a stout chain, while a man walking behind prevents it from trailing along the ground. By this method the only damage done is that caused by the wheels, but the seedlings, which they bend down, get straight again afterwards. The employment of limbers and horses may be avoided by using portable square frames, standing from eight to twelve inches above the ground, and fitted above with fixed parallel rollers, working in sockets. The log to be transported being placed on the rollers of two such frames, it is pushed on to a third frame placed in front, and so on.

RULE III.—The object of the third Rule is principally to insure the preservation of reserved trees. Its importance is considerable both in high forest and coppice, in the first to obtain reproduction, in the second to enable the different classes of reserves to reach a ripe age. Reserves are chiefly exposed to being uprooted or broken off by the wind, and hence it is of the highest consequence to leave a mass of old untouched forest between them and the dangerous winds. By this means the wind simply passes overhead without doing them any harm.

In France dangerous winds generally blow from the

south and west. They are violent and frequently accompanied with heavy rain, which soaks the soil and diminishes the stability of the trees. Hence felling operations should begin from the north and east. But local conditions may modify the general rule. For instance on the Mediterranean coast between Béziers and the Spanish frontier, violent and rain-bearing winds may blow from the east. Again in certain valleys, the spur of a mountain or hill may change the original direction of the wind. Such circumstances must be taken into account in determining the direction in which the successive cuttings ought to follow each other. In the absence of other indications, it is always easy to ascertain for a given locality the quarter from which dangerous winds blow, by observing on what side trees lie when they are blown down.

When the cuttings reach the edge of the forest struck directly by the wind, it is always necessary to leave a protecting belt which must be constantly kept well stocked and worked by selection. The breadth of this belt will vary with the violence of the wind, but under any circumstances to be of any real use it can seldom be under 100 yards.

It may happen that owing to former exploitations the oldest crop is situated exactly on the windward side of the forest. In such a case felling operations must of course be undertaken there, but nothing prevents our observing the desired order over at leas the area under this crop. And here again the necessity presents itself of preserving on the selection method a protecting band of sufficient breadth.

It is chiefly in mountainous regions, on the sea coast, or on the edges of unsheltered plateaux, that this rule must be rigidly followed. In the majority of cases it loses its importance in the plains in those forests where the oak is the dominant species. Nevertheless it is always prudent to conform to it, whenever the ages of the different crops are sufficiently well graduated not to entail any serious sacrifices.

Besides the reserves, the underwood also must be taken into account. Though it has nothing to suffer from the violence of the wind, still it has much to fear from the cold dry winds which blow from the north and east. This danger is most marked in the north-east of France, especially on the unsheltered plateau of the Ardennes. This is not, however, a sufficient reason for changing the general direction in which the cuttings ought to succeed each other, It is quite enough to leave a belt on the north-east, which should be worked by selection. Not being exposed to violent wind, this belt may be narrower than in the preceding case, thirty or forty yards for instance.

RULE IV.—In a mountainous country it is the higher parts which are exposed to the wind. The trees there are generally shorter-boled, but more spreading, more firmly rooted, and growing wider apart than in the less elevated situations. Their stability is therefore greater, and their presence is a protection to the trees lower down, which, being taller and less firmly rooted, could not stand without some shelter. This consideration indicates sufficiently

clearly along what direction the regeneration cuttings should be made. But on the other hand, self-sowing will always be obtained more rapidly if the seeds shed by the reserves of any one cutting are supplemented by other seeds coming from above.

Notwithstanding the advantages pointed out, the fourth rule has often to be neglected, since it may be opposed to the observation of the second. It is obviously futile to regenerate the lower portions of slopes, if the seedlings on them were subject to be destroyed by the clearance of cuttings situated above. Moreover, if the crops above contained mature timber, and those lower down growing timber, no one would think of working the latter first.

Hence the first and most important thing to do in a mountainous country is to lay out a good network of roads, which will divide the slopes into parallel zones and flank the cuttings on one side at least.

If the declivity is too rapid for cart roads, slides may be constructed, and if this also is impracticable, owing to material obstacles or steep inclines, shoots might perhaps be made available.

However, when it is possible to observe the fourth rule simultaneously with the second, there is every advantage in doing so, and it ought to be done. But if it be not possible to combine them, the second rule ought to prevail, as being the more important of the two; and to avoid the dangers against which Rule IV. provides, though the cuttings have to begin at the top, the more elevated portions, which afford protection, should be left intact and be worked by selection. It is impossible to indicate what amount

of protection is required in any special case. The width of the belt worked by selection cannot but vary with the height and form of the mountain. In the case of mountains higher than the limit of forest vegetation, the protecting belt should begin at least 200 yards below this line. If the summits themselves are wooded, the portion of forest treated by the selection method ought to include them as well as the higher slopes for a distance of from 100 to 150 yards. It is not always on the most elevated spots that the force of the wind is greatest, for it is quite as violent in the gorge formed by two contiguous mountains and on the pass between them. Here also the forest ought to be kept completely stocked, and worked by selection. It is from having neglected this precaution and the teaching of Rules III. and IV. that we have to deplore the gradual and complete denudation of large forest tracts. It is now extremely difficult to restock these areas. Under any circumstances restocking is very expensive, and must often be effected with temporary species, it being impossible to introduce the permanent and proper species of the locality at once.

RULE V.—It is obvious that if the longest dimension of a cutting is perpendicular to the direction of dangerous winds, the winds soon blow over it, and even if a few trees are broken or uprooted they do not bring down others in their fall, as would be the case if the wind blew in the direction of the length of the cutting.

PART VI.

GENERAL NOTIONS ON ARTIFICIAL RESTOCKING.

CHAPTER I.

GENERALITIES.—In every rational method of working a forest, reproduction ought to be the result of the cuttings themselves. This is one of the essential objects of the science and art of sylviculture. Thus in the different kinds of high forest, reproduction is obtained from seed shed by the trees under conditions favourable to germination, while in coppices it is obtained just as naturally by means of the shoots principally, and secondarily by means of the seeds furnished by the standards. But whatever the precautions taken, in both descriptions of forest there are often spots where seedlings do not come up, or where stools die and leave blanks. At other times it may happen that the reserve does not contain a sufficient proportion of a given species, a mixture of which is necessary, or that this species has disappeared owing to indiscreet operations, or the total absence of all operations. In each of these different cases recourse must be had to artificial means in order to restore the good condition of the forest, or a satisfactory composition of the crops. But such means ought to

be the exception, not the rule. It cannot become general and take the place of natural methods. We have noticed the circumstances which justify it in our summary of the treatment of forests of oak and of Scotch fir. To abandon natural reproduction is only to retrograde, to return to the infancy of the art; it is tantamount to claiming to supersede the forces of nature; above all it is simply wasting money under the false idea of economy, only to arrive in the end at results which are at the best doubtful.

Nevertheless, artificial restocking cannot be totally proscribed. It forms the necessary complement of natural regeneration, but it must remain only its complement. Hence it is necessary for the forester to know how to do it well. Besides this, it is the only method of stocking extensive treeless wastes.

CHOICE OF SPECIES.—There can be no hesitation in this choice, nor should it ever be allowed to furnish an occasion for the indulgence of the fancy. Thus the forester has to take into account the soil and climate, so that he may not be guilty of planting the peduncled oak on a dry soil, the silver fir in the plains or in a southern aspect, the sweet chestnut in calcareous soil, the cluster pine in a cold climate, the beech in the plains of Provence, &c. Above all, he must invariably avoid introducing exotic trees, as if our native species could not furnish wood suitable for every purpose. France is a miniature world, where we find every kind of climate and soil with its indigenous vegetation, which is not deficient either in quality or variety.

But precisely because France presents such differ-

ences of climate, care must be taken that each tree is placed in its proper station. It is not enough that it grows in France; it should also be spontaneous in the district. For a long time people have been vainly trying to acclimatise* plants, *i.e.* to modify during successive generations the conditions under which they thrive. This is nothing less than a chimera; and whatever may be the duration of the experiment, whatever the appearances of success, the cork oak will no more be acclimatised in the Ardennes than the peduncled oak in Africa.

All that we can expect, is to naturalise* certain plants which would find in France the same conditions as where they are spontaneous. Still naturalisation is seldom complete. Thus wheat, if left to itself, would soon disappear in the midst of indigenous grasses. The same is true of those trees, of which the naturalisation would appear to be the most nearly effected. The Robinia (*R. pseudo-acacia*), though it ripens its fruit, does not grow from seed without cultivation, and can maintain itself naturally only by means of shoots and suckers. In the same way the plane tree, the Weymouth pine, &c., would also disappear without the constant intervention of man. In short, and we cannot repeat it too often, why seek in foreign countries

* To *acclimatise*, means, as the author explains, to modify the requirements of a plant, to create a variety capable of living under any given conditions of soil and climate, which are hostile to the original species; to *naturalise*, signifies simply to adapt a species to live away from its own habitat, in a locality, however, where it finds the same conditions of vegetation. In both cases natural reproduction by seed is an implied idea.

trees whose timber is inferior, or at the most equal, to that produced at home? Experiments in naturalisation must be restricted to ornamental trees, and entirely excluded from forests grown with a view to production.

Hence when it is necessary to have recourse to artificial methods in order to refill blanks or restore a species which has disappeared, or increase its proportion in the existing mixture, the forester must confine himself to species spontaneous in the locality. The same holds good in planting up large treeless areas. In either case he must imitate what takes place in nature. In the same district several species of trees may be found, but they will not all demand the same conditions of vegetation, nor will they all possess the same constitution. A species which to-day covers a wide area, has perhaps made its appearance after, and in consequence of the protection of, hardier species, which have at the same time improved the soil by their detritus. Here is a lesson to learn from nature; it is often absolutely necessary to have recourse to plantations of the Scotch or the Austrian pine* as nurses, in the very home of the silver fir. In this manner the introduction of this last tree becomes easier and surer. It is advisable to operate thus even in creating a new forest in the plains. If the oak requires but little nursing, the trees, with which it ought to be associated, cannot do without it. In this case, the birch, the Scotch pine, and the cluster pine would

* The Austrian pine in calcareous, and the Scotch pine in sandy s oils.

be extremely useful as nurses. Where the soil is sufficiently wet, it is often very advantageous to make at first a plantation of alder. Private proprietors would thus find a means of rapidly recovering their outlay, as the alder grows fast and shoots up freely from the stool. But these trees, which may not improperly be styled transitory species, ought, as far as possible, to be themselves indigenous in the district. In the absence of indigenous species possessing some value, it it advisable to employ the Scotch or the Austrian pine. The trees appear to suffer less than any other from removal to different conditions of vegetation. Of course brushwood, if any comes up, should not be destroyed. In a word, here as elsewhere, we must utilise the forces of nature.

CHOICE OF METHOD.—Which is preferable, to plant or to sow? This question has been very hotly discussed, and yet is simple enough. It has been said by some that nature only sows, and that since we cannot do better than imitate her, we too must sow. But they forgot that natural forces have time on their side, and that they always operate slowly and progressively. When a piece of land is left to itself, it covers itself with such plants as the soil can support. Grasses and weeds appear first; then brushwood, followed by shrubs; then hardy trees, which demand little from the soil, and suffer nothing from complete exposure; and last of all, when the soil has become richer and moister, the more valuable trees come up under the shelter of the first, and maintain themselves by abundant seeding.

It is not possible for the forester to operate thus.

If he has to deal with a soil already sufficiently deep and rich, and a hardy tree which requires no nurses, he can obviously have recourse to sowing. But there will always exist this capital difference, that he cannot sow as abundantly as is done in nature. Moreover, the seeds are exposed to many dangers before their germination. Besides being liable to rot or lose their germinative faculty, they are liable to be destroyed by animals which feed on them. Nor ought it to be forgotten that, in spite of every care, these seeds are not placed in the same conditions as those which are shed naturally by the trees.

For a long time it could with truth be said that sowing was less expensive than planting, as it was the practice to make use of old seedlings, and put them out too close. But it is now an established fact, that the younger the plants are, the greater are the chances of success. With the exception of the silver fir and the beech, which it is dangerous to put out before the age of three or four years, all forest trees, especially the pines and the spruce fir, ought to be put out earlier, or, at the latest in their third year. Certain considerations, which we shall discuss further on, and which are entirely special, can alone determine otherwise. In this manner the rearing of the seedlings becomes easier, their putting out less expensive, and ultimate success much more certain. By employing only the number of seedlings necessary, planting can be made as cheap as, and sometimes cheaper than, sowing. Moreover, if care is taken that the plants are not put out before the dangers which threatened them in the seed have

ceased to exist, and if the operation is performed with equal precautions, it will be easy to convince one's self that, all things well considered, planting is more expeditious, more certain in its results, and more economical than sowing.

It is more expeditious, because, only plants of a certain age being used, failure can be detected the very first year, and be thus repaired at once. In sowing, on the other hand, success or failure cannot be appreciated until after several years. Notably in the case of the Scotch pine, many of the finest seedlings die from the disease termed *defoliation* between their third and sixth year.

It is more certain, because in the first place the success of sowing depends on the quality of the seed used, and as in most cases this has to be purchased, there is always the risk of obtaining seeds which are old, rotten or dry, or gathered before they are ripe; and in the second place, if the seeds are good they are liable not to germinate, or if they germinate to be choked up in the midst of rank, herbaceous vegetation, &c., &c.

It is more economical, first, because, owing to uncertainty about the quality of the seeds, more is sown than is necessary, and if all these sprout, the young plants come up sickly, in consequence of being too close together; and second, because, if there are empty places, where the seed has failed, these must be planted up, an operation, which from the blanks being far apart, sometimes costs as much as the previous sowing.

Notwithstanding the unquestionable superiority

of planting, the method of sowing is not to be absolutely proscribed. It may be used when seed is abundant and cheap. It should even be preferred to planting when there is a scarcity of labour, or when the season favourable for planting operations is short, or when the area to be planted up is large.

Besides the methods of planting and sowing, artificial restocking may also be effected by means of *slips** and *layers*. A *slip* is a branch of a plant separated from it and put into the ground in order to promote the development of roots, and thus render it an independent individual. A *layer* is a branch which is bent and laid in the ground, but is not separated from the parent stem, until it has thrown out adventitious roots. But these methods, which will be treated of further on, are employed only exceptionally.

SELECTION, HARVESTING AND PRESERVATION OF SEEDS.—To have no doubt about the quality of the seeds, they must be gathered personally and from picked trees. Thus those trees ought to be preferred, which are completely fertile, and at the same time sound and vigorous. Very young trees furnish many barren seeds, while very old ones yield seeds which produce weak plants. Deformed trees also ought to be avoided, as they give rise to defective varieties. In a word, one cannot be too careful in the selection of trees for seed-bearers. Unfortunately it is often impossible to exercise complete supervision.

* The term in common use is "cutting;" but as this word has already been used for an operation, in the sense of "felling," we have preferred the less familiar word "slip," believing that the essence of a good terminology is the absence of all ambiguity.

The method of harvesting must vary with the species. For such trees as the oak, beech, &c., whose seed is heavy, we may wait until it falls off naturally. But it is advisable to reject the first seeds that fall, as they are generally barren, or punctured by insects. To this end, it will be well to rake up the leaves and bad seed, just before the moment of maturity arrives. We cannot, however, wait for natural dissemination in the case of trees with light seeds. They must be gathered by hand as soon as they are ripe, and before they fall. The seed of the conifers is also hand-gathered, the silver and spruce firs immediately they are ripe in the autumn, pines during autumn and winter, before the warm days in spring come round again. We shall show later on how the seeds are extracted from the cones.

Whatever the species, the seed must not be gathered during rainy weather. If the seeds are heaped up while wet they are apt to become heated. Even when gathered on a dry day, they should not be placed in a heap without being previously spread out, and stirred about to remove their superfluous moisture.

Nothing is more important than the preservation of seeds, and yet nothing is sometimes more difficult. Besides guarding against germination, they must be prevented from fermenting, rotting, or drying up. Seeds of some trees can under no circumstances be kept, and should therefore be sown immediately after being gathered. Such are the seeds of the different elms, of the birch, alder, &c.

To prevent germination, it is sufficient to with-

hold one of the three necessary conditions, viz., oxygen, moisture and heat. But in doing so, other dangers arise. Fermentation and rot can be prevented by taking care not to place the seeds in high heaps, and above all by being careful, as soon as they are gathered, to spread them out in a well-aired place, and to stir them about once a day for a fortnight. At the same time they must not be allowed to dry too much; to that end they should be kept in a place which is cool without being damp. The seed of conifers can be preserved for more than a year by leaving them in the cones, which must not be piled up too high, and which must be stirred about from time to time. But seeds which have been kept for more than a year are never trustworthy: many lose their germinative power, or do not germinate until a year after being put into the ground. Moreover, it is worthy of remark that plants grown from old seeds are weakly and usually of no promise.

We have seen from the above considerations that it is always better to sow seed as soon as it is gathered. But this can seldom be done, as in that case a large quantity must be used to make allowance for the numerous causes of destruction; and the price of seed forms a heavy item of expenditure. This again is another argument in favour of plantations, for then the young plants are brought up in nurseries, a circumstance which diminishes to an extraordinary extent the quantity of seed necessary, and it is always easier to preserve a small quantity.

According to the kind of tree different methods

have been prescribed for the preservation of seed. The following are to be preferred. Large seeds like the acorn, chestnut and beech-nut, cannot be kept longer than from autumn to the following spring. If the quantity is small, they may, after being spread out and stirred about for a fortnight, be placed in layers three to four inches deep between alternate layers of pure and perfectly dry sand, or of straw. They are thus put away in cellars in chests or barrels supported on trestles. If the quantity is large, they may be kept in the same manner in pits dug in a dry soil and built round with masonry to keep out mice. When the quantity is considerable, the best course is to lay the seeds out in a heap four to eight inches high, to stir them about now and then, and cover them up with dry straw to keep out frost. Immersion in water is often impracticable and yields only indifferent results; it is entirely unsuited for the beech-nut.

At the moment of sowing, one can judge if the seeds are still good, by examining whether the kernel fills its shell completely, whether it is still white and fresh, whether the germ is still sound, whether there is no mouldy smell, and, in the case of the beech-nut, whether it has preserved its agreeable taste, resembling slightly that of the hazel-nut. Seeds ought not to be rejected if the rootlet has begun to develop itself, or even if it is broken.

The hornbeam and ash do not generally germinate until the second spring after their fall; these seeds are liable to dry up. As these two species strongly object to herbaceous vegetation, and delight in very

moist and even wet soils, it is impossible to sow them directly in the forest. They keep well enough when placed in holes of little depth dug in the ground, and covered over with earth. They may be left thus until the second spring. Hornbeam seeds are still good, if the kernel is white and moist; seeds of the ash ought to retain their bluish tint and the consistency of pure wax.

Maple seeds are also liable to dry up; hence they ought to be kept in a cool place, which is not wet, and they must not be heaped too high. On examining the kernel, it is not enough to find the characteristic green colour, because this remains even after the seed is quite dry; the kernel must also show traces of moisture when crushed.

We have already seen that it is impossible to keep the seeds of the elm. This is no inconvenience, because they ripen about the end of May or beginning of June. Also, when sown immediately, they germinate the same year; only by reason of the heat of the season, it is good to shelter the seedlings during the first few months.

Among conifer seeds, those of the silver fir require great care. They must be handled as little as possible, their wings should be preserved, and they must be gathered near the spots to be sown. In years of abundant seed, when they cost little, it is even preferable to sow them immediately after being gathered. They cannot, indeed, like other conifer seeds, be kept in the cone, since the scaly bracts break off at the moment of maturity and fall with the seeds.

CHAPTER II.

PLANTING.—Must natural seedlings obtained from the forest be used, or is it better to bring up the plants in a nursery? The answer admits of no hesitation. In a nursery the soil is prepared by cultivation; the roots therefore develop rapidly, and a seedling can never have too many roots to succeed. The extraction of the plant is more easy, and the fibrous roots do not require such careful handling. The taproot, which in certain species is very long, can be shortened either at the time of transplanting in the nursery itself, or by cutting it off *in situ*. By this means the roots gain a lateral development, and do not sink deep; hence smaller holes are necessary, and the operation of putting out is done better and more rapidly. Lastly, it is in nurseries alone, and after special care, that we can obtain vigorous young plants.

Nevertheless, in the absence of nurseries young seedlings from the forest may be used. Those are to be preferred which have grown in open places and not too thick together. Such plants have a better developed crown and stronger and more numerous lateral roots. In the case of broad-leaved trees stunted plants are the best; they possess well developed roots, while the form of their crown is of no consequence, since they may be cut back on being planted. Those seedlings which are drawn up, and are

as yet branchless, have generally a single long root, of which a considerable portion is left in the ground, or is necessarily lopped off; they succeed with difficulty unless they are not more than two years old. As for conifers, with the sole exception of the silver fir, which cannot stand transplanting before the age of three years, the younger the plants are the better.

NURSERIES.—The first question to settle is that of site. It is not necessary to establish a nursery in the forest itself under the pretext that the young plants will suffer less by remaining in the same soil. Whatever the soil into which they are ultimately to be put out, the nursery should be situated in deep soil of good quality, on horizontal, or rather slightly inclined ground, sheltered, but not entirely so, and in the proximity of a spring or stream if that is possible.

In deep soil of good quality the seedlings will be vigorous and well furnished with roots, and will, therefore, evidently resist the risks that attend the operation of putting out better than others. The mineral composition of the soil is of little importance because in a nursery it is modified by the mould or manure put into it. Nevertheless sandy loam is to be preferred. The ground must be slightly inclined, to avoid an excess of moisture, but not too much so, in order to escape the opposite extreme. An eastern or south-eastern aspect is the best, because there the season of vegetation does not begin early, and there is less danger of late frosts. A nursery must not be placed in the midst of a lofty mass of forest; for being shut up on every side, the air circulates

there with difficulty, a circumstance favourable to frosts. Lastly, it is a great convenience during drought to have a spring or streamlet near at hand from which to water the seedlings.

The site once fixed, the area of the nursery is determined by the object for which it is wanted. If it is to be a permanent one, it should be made pretty large. A single nursery is better than several small ones; it is better looked after, especially if it is placed next to a forester's house. But it must not be so large as to render supervision difficult, and it is advisable not to let it exceed five acres. If only temporary nurseries are required, they may be small and their number increased as wanted. No manure is used in such nurseries, the mould contained in the soil being sufficient for all purposes. In the majority of cases no clearing is made; the nurseries are established in glades or blanks near the spot to be planted.

It is always advantageous to fence in a nursery. This is indispensable for a permanent nursery, and for those in which acorns or beech-nuts are sown, to protect them against wild pig. The attacks of the small rodents can be avoided by sowing late in the spring, just before the season of germination. As for birds, so fond of conifer seeds, there is no other way of keeping them off than by posting a watcher armed with a gun to scare them.

Before sowing a nursery, the soil must be cultivated and that too, deeply, in order to render it light; at the same time it must be freed from stones. But in turning up the soil care must be taken not

to bring the subsoil to the surface; for not having undergone weather influences, it does not contain elements capable of assimilation. Deep cultivation is justified by the fact that it admits air into the soil, causes the roots to develop rapidly, and while permitting the infiltration of rain-water, opposes drought. This is a fact proved by experience, and the reason of it is, moreover, clear.

If this turning up of the soil produces more vigorous seedlings, it presents, on the other hand, the danger of favouring equally the development of herbaceous vegetation. For this reason it is prudent to obtain previously one or two agricultural crops, preference being given to plants which require hoeing and weeding, such as the potato, Indian corn, &c. Afterwards only should plots be laid out to receive forest seeds.

To this end the nursery is divided off into beds running in the direction of the slope of the ground. They are given an average breadth of three feet, and are separated by paths one foot wide. Lastly, the paths are made to terminate on roads which divide the nursery into compartments. The seed is sown in the beds either broadcast or in furrows. The former method may be adopted when the seedlings are to be transplanted into nursery lines before being finally put out, or are to be put out in patches of several together at the age of one year. But it is nearly always preferable to sow in trenches or furrows running parallel to the width of the beds.

For large seeds these trenches are made with the spade. For small seeds, and generally for those

of conifers, it is better to make them with a plank as follows. After having well broken up the soil at the surface and made it even with a rake, the nurseryman places this plank on the ground; it should be pretty thick, about ten inches broad, and fitted on the under side with two parallel bars hollowed out in the shape of a gutter. By treading on the plank or otherwise pressing it down, the bars are forced into the ground. On taking up the plank two trenches are seen, each consisting of two furrows separated by a slight ridge. The seed is sown along the top of the ridge, and falls down on each side into the furrows. Nothing more now remains to be done but to cover the seeds over with mould or fine earth of good quality.

The advantage of this method consists in a great saving of seed and its regular distribution. The young plants springing up in one line, do not interfere with one another, and develop freely on each side. In sowing broadcast or in slightly wide trenches, the inside plants soon begin to suffer, especially if the seeds have been sown thick. A large number remain sickly, and are fit to use only after transplanting. Hence when the plank is not employed, it is expedient to make the trenches narrow, to leave a space of four to six inches between two consecutive trenches, and to sow the seed in a single row in such a manner that they may touch one another if large or be a few millimètres apart if they are small.

With the exception of seeds very difficult of preservation, such as those of elm, birch, alder,

poplar, and willow, which ought to be sown as soon as they are gathered, the most favourable season for sowing is spring time. It is even necessary to sow a little late to escape the action of frost; the end of April or the beginning of May is best suited for the greater portion of France. But in that case there is the danger of drought and the heat which ordinarily follows the equinoctial showers. The seeds, therefore, for want of sufficient moisture, may not germinate. This is remedied by soaking them in water, or still better in liquid manure. The length of immersion varies with the size of the seeds and the hardness of their pericarp, and ought to last from twelve hours to several days. Larch requires the longest soaking. By this means the seeds absorb the moisture necessary for their germination, and under the influence of the first few warm days they germinate at once. The principal causes of destruction are thus averted, viz. animals and extremes of the weather.

It is very difficult to state precisely the quantity of seed to be used in a nursery. It depends above all on their quality and also on the age at which the seedlings are to be put out. If one year old seedlings are wanted or if the seedlings are transplanted into nursery lines, the seed may be sown pretty thick; in other words, the young plants may be allowed almost to touch one another. If the plank is used or if the seed is sown in similar narrow trenches, a row of three feet long would contain from one hundred to two hundred seedlings. Thus, if the seed is of average quality, *i. e.* if two-thirds are good, it would

be necessary to sow from 150 to 300 seeds for the same length. Hence it appears convenient to ascertain the number of seeds contained in a certain weight or volume. Experiments made at the nursery of *la belle Fontaine* near Nancy have yielded the following results:—

TREE.	Volume.	Weight. oz. avoir.	Number of Seeds.
Scotch Pine without the wings ...	1 gallon	82	319,500
Austrian „ „ ...	„	84	113,000
Cluster „ „ ...	„	96	59,900
Weymouth „ „ ...	„	66	113,400
Silver Fir „ ...	„	46	40,000
Spruce „ „ ...	„	90	310,500
Larch „ ...	„	78	279,000

As these seeds are generally sold by weight it follows that—

1 pound of Scotch Pine seed contains 62,500 seeds.
„ „ Austrian „ „ 21,500 „
„ „ Cluster „ „ 9,800 „
„ „ Weymouth „ „ 27,500 „
„ „ Silver fir „ 13,900 „
„ „ Spruce „ „ 55,200 „
„ „ Larch „ 57,200 „

To this list may be added the hornbeam, of which one pound without the involucre contains from eleven to fourteen thousand seeds.

Beech-nuts and acorns are usually sold by the bushel. A bushel of the former weighs on an average from thirty-four to thirty-six pounds, and contains about 51,000 to 55,000 seeds. As for acorns, they vary so much in size that it is difficult to lay down any rule for them. The peduncled

oak, whose vegetation in good soil is rather more regular than that of the sessile-flowered variety, yields for a bushel a weight of from 40 to 48 pounds and 8,000 to 9,500 acorns.

These are obviously only general indications, which must be modified, according to circumstances, by the means of supervision available, and by the dangers and enemies to which seedlings are exposed at the moment of germination.

When the seeds have been scattered, they are covered over with just enough earth to protect them from birds and to prevent the rain from laying them bare. For this purpose mould prepared in the nursery itself, or very fine earth, is used with advantage. A covering of a third of an inch is the best for small seeds such as those of the spruce fir, Scotch pine, &c. For the larger seeds, such as the acorn or beech-nut, or for those which have a woody pericarp, like the hornbeam, drought must be provided against, and hence it is expedient to go as far as one inch.

It is sometimes prudent to shelter the young plants at the moment of germination and against drought during the first year. Twigs laid flat on the ground or stuck in between the trenches answer well. It is above all shelter rather than cover that is needed, and consequently the nurseryman will avoid the constant use of thatch supported horizontally at a certain height on pegs. Broom, furze, and branches of the conifers are very convenient for this purpose. For a long time it was believed impossible to raise beech and silver fir in open nurseries on account of the delicate constitution of the young

plants of these species. It had nevertheless been remarked that beech seedlings taken from the forest at the moment of germination, could be transplanted in an open place, provided they were put into the ground up to the cotyledonary leaves. The fact is, that it is the young stalk which is the most sensitive part. Hence a new plan has been devised for these species. Narrow trenches are dug and the earth heaped up on the edges, so that the trenches have a depth of about four inches. The seed is sown at the bottom, and as the young plants grow up, the earth is put back into the trench till the ground becomes level. This plan has never failed, especially when care has been taken to dig the trenches east and west, so as to shelter the seedlings on the south side.

The soil of the nursery becomes rapidly exhausted, since it no longer receives the dead leaves or the constant shelter which the leaf-canopy formerly supplied. Moreover, it becomes poorer in the inorganic elements of the young plants. It is therefore necessary by fresh manuring to give back what it has lost. These manures may be either farmyard refuse or guano or soluble salts, but in the majority of instances, mould prepared expressly in a corner of the nursery is used. For this purpose leaves and herbaceous plants are collected and heaped up after being mixed with fine earth, and the whole is sprinkled from time to time with water or still better with liquid manure. This mould is used especially in covering up seeds. If there is no mould available and the nursery is to be maintained in the same

place, it becomes indispensable to let the land lie fallow, and to have it dug over several times during this interval. In this way a third or fourth of the whole area is allowed rest every year.

When the nursery has been thus prepared and the seeds have germinated (this takes place before many days are over, if the seeds have been first soaked in water or liquid manure) certain operations become necessary for the well-being of the young plants. These are watering, earthing up, weeding, and hoeing.

Watering must be sparingly resorted to, unless it is effected with a forcing pump whose spout is furnished with a rose. In that case the water reaches the ground in fine drops, that soak in at once. When ordinary garden pumps are used, the water forms mud with the uppermost layer of the ground, and thus a superficial crust, impermeable to air, is created. Besides this, this watering must be continued till the first shower of rain restores the ground to its original condition, unless the crust is in the mean while broken by light hoeing. Whether ordinary garden pumps or forcing pumps are employed, the water ought to penetrate as far as the roots to produce any useful effect.

If it has been possible to establish the nursery in the proximity, and a little below the level, of a spring, the best plan is to irrigate. For that purpose the footpaths which separate the beds ought to be horizontal and slightly lower than the trenches. Water is introduced into these footpaths and retained there by means of little dams till the ground is well

soaked. In this manner the surface is never washed away and the permeability of the soil is constantly maintained.

As in the cultivated portion of a nursery, the soil is thoroughly loosened, a consequent subsidence of the ground cannot be avoided, by which the seedlings may be laid bare as low down as the roots. The same result may be produced by frost. To remedy this evil it is sufficient to spread mould or very fine earth until the plants are covered as high as before.

In light or limestone soils this laying bare of the seedlings by the frost is often fatal, and the best plan to avoid it is to place straw or dry leaves on the trenches at the beginning of winter. This bedding is removed in the spring after the frosts are over.

The operation of weeding consists in the removal of the herbaceous vegetation that may have come up along with the seedlings. Grasses are dangerous because they grow more rapidly than the latter, their tufted roots take complete possession of the ground and their stalks form a close, and therefore all the more harmful, cover. When the term of their maturity arrives, they seed abundantly. After the season of vegetation is over, they lie on the young plants and smother them. Hence they should be got rid of as soon as they make their appearance, and especially in rich or moist soils.

If the soil of the nursery has been previously prepared by a crop of plants which require weeding (such as the potato, Indian corn, &c.) there is little to fear on this score during the first year. The danger is still further diminished if the trenches are

close together, for then the seedlings soon cover the whole ground. But whatever the precautions taken, grass cannot always be kept down; it must be plucked out with the hand, the operation being facilitated by making the beds narrow, in order that the weeder may reach the middle without leaving the footpath.

Even if no grass comes up in the trenches among the seedlings, it is always necessary to remove that which grows on the paths and roads in the nursery. This must be done at the latest before the seeds ripen. All the stuff obtained from weeding should be collected to prepare the mould already mentioned.

Hoeing is an operation by which the soil is loosened at the surface, being a species of second working up to which it is subjected. It is not always resorted to in nurseries, and has its *raison d'être* only when it is proposed to raise plants of some size. In this case of course, it is necessary to increase the distance between them, and give them more free room by transplanting them. The ground, being then no longer completely covered, becomes hard, and may be overgrown with grass. This is the time for hoeing, by which the soil is broken up and at the same time freed from grass. It has sometimes been said that the hoe should not be used during drought. Experience, however, proves otherwise by showing that a well-loosened soil dries to a less depth and condenses more dew than the same soil in a hard and compact state. This is equivalent to saying that hoeing done at the right moment is as good as watering.

Seedlings are divided into three classes according

to their size: (i) small, (ii) medium, (iii) tall. The first class comprises all those below three feet in height; the second those between three and six feet; the third those above six feet. Small plants ought always to be preferred, unless special circumstances preclude their use; success is more certain with them. The success of a plantation depends chiefly on the condition of the seedlings, which can never have too many roots; now it is impossible to extract a plant of some size without leaving a considerable portion of the roots behind in the ground, and the older the plant, the greater will be the number thus left. Hence it is recommended to use seedlings of one, two, or at the most three years for nearly every species. Medium and tall seedlings should be employed only in restoring a species where other seedlings already exist, or in wet places where tall grass is to be feared, or finally when it is proposed to grow pollards and those special trees of which nearly all the branches are lopped off.

If the seedlings used belong to the smallest category, and have been raised in the nursery in furrows or narrow trenches, they are put out directly. But if they have been sown broadcast, or in trenches from ten to twelve inches wide, and are to be put out only in their third year or so, those in the middle are often weakly and ill-supplied with roots and foliage. Putting them out directly from the seed-bed would result in almost certain failure. It is better in this case to transplant them in nursery lines, giving each a clear space of about four inches in every direction. The soil being first well loosened,

the seedlings are put into the nursery lines either with the hand or with the aid of a frame, constructed as follows:—the frame is of wood, oblong in shape, and of the same width as the bed to be planted up. Small notches are cut in two opposite sides at intervals equal to the distance proposed between two consecutive plants, and large enough to receive a movable flat bar. This bar contains slits or openings in which the seedlings can be moved about freely. To set to work, the frame is placed on the bed, and a trench is opened of which one side is vertical. A seedling is passed through each slit in the flat bar, which is then placed over the trench and supported on two opposite notches in the frame, and earth is heaped up against the roots of the seedlings. To render the operation expeditious, this earth is obtained by hollowing out the trench to be planted next, so that a second trench is ready as soon as the first is filled. The nurseryman proceeds thus until the whole length of the frame is planted up, and so on with the remaining beds.

The raising of seedlings of the other two classes also involves the necessity of transplanting. Tall seedlings ought even to be transplanted several times, increasing the interval between two consecutive plants at each operation; but they ought always to be near enough to close up their crowns and allow the lower branches to fall off naturally without necessitating pruning.

At the time of transplanting or trenching it is essential to make a clean section of such roots as are broken or damaged. Even if the roots are intact

it is necessary to cut off a portion of the tap-root in the case of species in which it is long. The object in view is to provoke the development of lateral roots which present themselves on a swelling round the section. These lateral roots being nearer the surface, are easy of extraction and require smaller holes when put out. Certain species, such as oak and even the beech, develop a strong tap-root from the first year, which it is impossible to pull up without breaking. Moreover, the preservation of the tap-root would require too deep a hole at the moment of transplanting. Besides this, the tap-root remains for some time the sole root of the seedling, or presents only few and insufficient rootlets. This is a circumstance unfavourable to the success of the transplants. It is remedied, when the seedlings are not removed into nursery lines, by cutting off the tap-root *in situ* underground. For this purpose a spade is employed the bade of which is flat and about twenty inches long, terminates in an oblique edge, and makes a certain angle with the handle. The instrument ought to be strong, sharp, and of good steel. The seedlings having been sown in narrow trenches, the spade is pushed into the ground on either side of each trench, so as to cut off a portion of the roots of every plant. The notches made by the implement are pressed down with the foot. This operation is generally performed in the autumn of the first year, and from the very commencement of spring, numerous lateral roots, are observed to develop all round the section. Unfortunately this implement cannot be used in all soils; thus stones

in the soil destroy the edge, and prevent it from penetrating; too stiff a soil clogs the blade, and renders it necessary to dip it each time in water; when the soil is very light, the young plants are pushed forward along with their roots, against which the spade strikes without cutting them.

When it is required to extract the seedlings before putting them out, every precaution possible ought to be taken to keep the roots intact. In the case of tall plants, they must be taken out one by one. To that end, by means of a spade, a circle should be traced round each plant, large enough to avoid the lateral roots. They should then be dug away, care being taken not to damage the fibrous roots; when a sufficiently deep hole has been made, the tap-root must be cut through obliquely. If the seedlings are small and have been raised in parallel trenches or furrows, the best plan is to make a small trench of sufficient width alongside the outer edge of the first one of all, and then to tilt over the seedlings into it with a spade pushed into the ground on the other side. This being done, the soil adhering to the roots is gently shaken off with the hand. Lastly, in the case of one-year-old conifers, the seed-bed may be cut up into sods like turf; the young plants are separated only at the moment of planting.

The seedlings ought to be used as soon as possible after their extraction; but this cannot always be done, for nurseries are sometimes at a considerable distance from the spots to be planted up. In that case, immediately after their arrival, they should be unbound and put into a trench without being packed

too close together; such roots as show signs of mouldiness should be removed, and the whole must then be covered with fine earth. In this case, moreover, the plants are extracted only at the moment of despatch, and put up in loose tufts, the roots being enveloped in moss. Sometimes when the transport is long, the roots are still further protected from contact with the air by plunging them in thin mud, composed of clay and water.

PLANTING, PROPERLY SO-CALLED, OR PUTTING OUT. —The first question which presents itself is "what is the most favourable season for planting?" Except in the case of planting out in sods (like turf) in which the roots remain entire, it is undeniable that the operation ought to be done while vegetation is active. During the remainder of the year, it is evident that the season of frosts is highly unfavourable. There is therefore no choice left but between autumn and the beginning of spring. If it be remembered that the welfare of the plants depends on the state of the roots, it is at once seen that autumn is to be preferred to spring. The drought which follows the vernal equinox exposes the fibrous roots to dry up rapidly. Now the fibrous roots, in other words, the finest extremities of the roots, constitute the organs of absorption, and their entireness is the first condition of success. Moreover, in the case of seedlings a little old, the alternance of frost and rain, which characterises the close of the season of vegetation, produces complete contact between the roots and the soil. But on the other hand, when seedlings are put out quite young, frost,

by causing the soil to expand, compels them to follow the upward movement, and when thaw sets in, the young plants run the danger of having their roots laid bare. It cannot therefore be laid down as an invariable dictum that autumn is preferable to spring or *vice versâ*. The question is entirely one of local conditions. Besides, this choice does not always exist, and if large areas are to be planted up, there is no alternative but to distribute the work between the two seasons. The essential thing is to plant carefully.

To that end the forester must first occupy himself with pit-making, the interval to be left between the pits, the pruning of the seedlings, and putting them into the ground. In the second place, he must examine the different methods of planting.

The pits ought to be deep enough to enable the plants, with *all* their roots, to be put into the ground in perfect freedom, and as low down as they were before. As for tall seedlings, for which large holes are of course necessary, it is an advantage to separate the different layers of soil, so that the best may be put in immediate contact with the roots. But whatever the class of plants used, it is always better to prepare the pits before they are wanted, in order to loosen the soil and subject it to the action of the atmosphere. Moreover, the work is done more

* Three principal results follow from exposure to the air, of which two are chemical and the third physical. They are as follows:

1. Formation of ammonia, and of nitrous and nitric acid, known technically as *nitrification* of the soil.

2. Transformation of insoluble into soluble substances; thus carbonate of lime which is insoluble is changed into bicarbonate of lime which is soluble, the decomposition of vegetable detritus is facilitated, &c.

3. (Partly a consequence of 2.) The cohesion of the soil is diminished.

systematically and economically, if the attention is given solely and exclusively, first to pitting and then to putting the plants into the ground.

The principle to act upon is to plant as economically as possible, and at the same time with all the necessary precautions. This amounts to saying that the number of holes should be just large enough to enable the plants to form leaf-canopy in a reasonably short space of time. It depends then on the rapidity with which the species grows and quality of the seedlings. Generally speaking an interval of from three to six feet is the best for small seedlings. This distance may be increased, if the area to be planted up is very large, and nature is left to fill up the intervals with any species whatever. It should be clearly understood that we have been speaking of complete blanks. When the object in view is only to restore a species in a mixture of other trees, it is enough to plant twelve to twenty feet apart.

We have seen that seedlings, and especially their roots, ought to be entire as far as it is practicable; and in this respect the utmost precautions ought to be used in their extraction and transport from the nursery. This condition is fulfilled easily enough with very young plants; hence these may be used without undergoing any kind of preliminary pruning. Such a proceeding is even indispensable with conifers, as they cannot be cut back, and have much to fear from wounds in the portion above ground. In the case of broad-leaved trees, if the roots have been damaged, the defective portions may be cut off clean and obliquely; and if the remaining roots are

insufficient to feed the leafy portion, this defect is easily remedied by cutting back the latter close to the ground. The shoots which then come up are the direct result of the vegetative force of the roots, and equilibrium is established between the two by the end of the first year. Among these shoots only one can survive on such a small stool, so that cutting back is no obstacle to the creation of high forest. More frequently when the seedlings have been raised in nursery lines, or when the tap-root has been shortened *in situ*, convenient roots will have developed themselves, which may be extracted entire. This is no longer the case, when one has to deal with tall seedlings. Do what one can, there are always broken roots which must be amputated, and vegetative equilibrium can only be established by cutting back the portion above ground. The only thing necessary to bear in mind is that it is better to have too many roots than to have too few.

Similarly too much care cannot be used in putting the seedlings into the ground. The roots should be placed in their natural position, in which they previously were. This is especially necessary in the case of plants already of some size. With them the roots, after being properly arranged, ought to be covered over carefully with the best layer of soil dug up, with that which has been subjected longest to weather influences. It ought to be broken up fine, so as to allow it to fill up all the interstices between the roots. At the same time it must not be pressed down too tight under the pretence of producing a more complete contact:

this is only a question of time. The remaining earth should then be thrown in. Less precaution is necessary for small seedlings. Frequently it is sufficient to hold the plant with one hand against one side of the pit, while with the other hand the roots are covered up. When the ground permits of it, nothing more need be done than plough up furrows at the distances required, and make holes with a dibbler as the work proceeds. It is always advantageous to place flat stones round each plant: these preserve the moisture of the soil and prevent it from swelling too easily during frosts.

Lastly, seedlings may be planted out individually, or in clumps, or in small mounds above the natural soil (ball planting).

Seedlings are planted out individually whenever they belong to the large or medium class, or even when they are small, if at the same time they are well grown. If they are put into the ground with care, success is very nearly certain, unless the year be extremely unfavourable, or the plants be too far apart. But if only one-year old seedlings are used, as is to be recommended for the Scotch pine, spruce fir, &c., it is always prudent to plant in clumps of two or three plants each. This is done in the hope that one at least will succeed, and if all live, one of them is sure to be more vigorous than the rest and overtop them. These latter will then form a bush round the first until they succumb to the cover, or are cut down, thus proving useful in preserving moisture round the roots of the more vigorous individual. To plant in clumps, it is best to sow the

seeds in the nursery in furrows in which the soil has been mixed with a large proportion of mould, and well loosened. The seeds must be sown thick, and in extracting the plants a slightly rainy day ought to be chosen. They can be easily removed from the bed by being simply pulled up with the hand, a small trench being previously dug alongside, or they may be cut up and carried away in sods like turf. This latter is the best way of keeping the plants fresh and vigorous, but the soil of the nursery is rendered proportionately poorer by it.

If the plants have been plucked up, they must immediately be put into baskets, to prevent the roots from drying up. For the same reason, during the process of planting out, only a small number ought to be taken out at a time in the hand. They should be arranged in groups of two or three each, and, to put them into the ground, an instrument resembling a mason's trowel in shape is used with advantage; with t the hole is made, and at the same time the soil is loosened. It is especially in this method of planting that it is advisable to place flat stones round each group.

Ball planting was principally commenced in Germany. In this method the seedlings most commonly used are of the first or smallest class, which have been transplanted into nursery lines and deprived of their tap root. Small conical mounds from eight to ten inches in diameter, and of the same height, are put in lines regularly laid out. These mounds are composed of mould specially prepared with leaves and grass. They are hollowed out at the top with

the hand. The seedling is put into the hollow, and its roots, after being properly arranged, are covered over with mould. Lastly, sods of turf are laid over the whole mound with the turf inwards, so that the mound is completely covered with only a hole at the top through which the stalk of the seedling passes. While acknowledging the effectiveness of this method, it is however fair to state that it requires a rather heavy outlay, and that excellent results may be obtained at less cost.

CHAPTER III.

DIRECT SOWINGS.

We have seen higher up that planting is generally to be preferred to sowing, provided the species employed are appropriated to the soil and climate, and the young plants are judiciously selected. Still it must be confessed that sowing has at times *raison d'être;* for instance, when labour is scarce or when large quantities of seed are procurable at low prices, or if the object in view is to introduce a new species under the shelter of that which is already in possession of the soil, or lastly if the time at one's disposal is very limited and the areas to be stocked are large. Hence it is necessary to give a few directions with regard to the plan to be pursued in these different cases.

Preparation of the Soil.—The first question which presents itself is how to prepare the ground. This may be done in three different ways; (i.) com-

pletely, (ii.) in bands, or (iii.) in patches. The first method is that least practised. The implement employed is either a plough or a hoe. The plough can be used only where the ground is not covered with large stones, and its slope is not too great. Whenever its employment is possible, the plough is to be preferred, because it requires a smaller outlay. But the cultivation of the whole surface demands a considerable quantity of seed; it is also more difficult to distinguish failure from success, and the repair of blanks is more laborious.

Cultivation in bands is superior to this. It consists in cultivating parallel strips of ground with the plough or the hoe from one to two yards apart according to the rapidity of growth, the angle of the slope and the object in view, the intermediate strips being left intact. The bands are given an average width of about ten inches, and in a flat country they are directed east and west, and care is taken to throw up the earth on the southern side. In this manner the seedlings are protected from drought during the first year. On sloping ground the cultivated bands are made narrower. Care is taken to level them in the direction of their length, and it is even desirable to give their width a gentle inclination downwards and heap up turf and earth on the opposite side. Band cultivation offers several important advantages; under any circumstances it requires less seed, although proportionately to the surface cultivated, it requires more than the first method. The vegetation which presents itself on the intact bands serves as protection against drought; on the other hand, it

cannot be denied that grass seeds are liable to spread into cultivated bands. But it is especially on slopes that this kind of cultivation asserts its superiority; the intact bands maintain the soil in its place, whereas complete cultivation would cause it to slip; the bands of loosened soil render the ground permeable to water, which they retain like so many trenches; dead leaves and detritus of all kinds accumulate and decompose near the seedlings; lastly, the seeds are not washed away by rain.

If the surface of the ground presents obstacles, or if it is required to economise labour and seeds, the patch method is adopted. Here the hoe is used. The patches are made square with a side of from twelve to twenty inches, and are disposed as nearly as possible along regular lines. Care is taken that turf is thrown upon the southern side on level ground, and on the lower edge on slopes. The distance between the patches varies with the species of trees and the difficulties which the ground presents.

In all these three methods of cultivation, it is important to loosen the soil thoroughly and at the same time to avoid bringing the deeper layers up to the surface. It is always advantageous to begin work the preceding autumn when it is desired to sow in spring, in order that the soil may be subjected to atmospheric action, and be more favourable to vegetation.

In connection with the cultivation of the soil, naturally come the subjects of surface-firing and drainage. A few words will suffice to indicate the extent of their importance.

Surface-firing consists in burning the vegetation which may cover the ground and oppose the growth of the seedlings. There are two methods of practising: it (I.) open air firing, (II.) firing in heaps. The first consists in setting fire to this vegetation without any preliminary operation, care being taken to prevent the fire from spreading. In the second method, the vegetation is cut up with the soil in sods and allowed to dry. After drying the earth is shaken off as far as is practicable, and the dry stuff burnt in small heaps. The ashes are then scattered over the whole surface of the ground. This latter process is especially applicable when the soil is wet and covered with rank grass. If patches of heather and furze cover the ground, it is advisable to pluck them up with the hand before firing. By this means their roots are killed, which would otherwise furnish a new crop heavier than the first. Surface firing destroys noxious vegetation, and also results, by means of the ashes, in the restitution to the soil of inorganic elements, which increase its fertility.*

* This statement admits of a doubt in the case of open air firing. If converting the vegetation, which covers the ground, into ashes yields at once a large quantity of inorganic elements, on the other hand all the organic elements, of which plants stand most in need, are volatilised, the surface soil is baked, and any vegetable mould and *débris* that may have collected since the last firing is totally destroyed. Active growth during the first one or two years is no proof that the soil is not impoverished; it is simply the effect of the ashes, which are soon exhausted. The Dhya cultivator in India only understands this fact too well; and a very casual inspection of the open jungle tracts in that country is quite sufficient to convince one of the injurious action of fires on the surface soil. The other method of firing is not so objectionable, as the soil remains un-

It has been asserted that the ashes also add to the lightness of the soil, and in consequence surface firing can be practised without danger only in stiff soils. In the first place it must be observed that light soils are seldom overgrown with grass, at least with thick tufts. In the second place the ash produced by the combustion consists of very minute particles and, therefore, forms a stiff rather than light soil. Who has not seen heaps of wet ashes, and who does not know that when they are dry it often requires a spade to break them? Hence if the soil in question is wet and overgrown with tall grass, rushes, &c., the best course is, instead of direct sowing and the risk of having the seedlings choked up, to plant it up with medium and tall seedlings.

As for draining, except in the case of stagnant pools, it must be resorted to with great moderation. The essential point is rather to appropriate the trees to existing local conditions. A few ditches judiciously dug ensure sufficient drainage, and it must not be forgotten that it is very moist and even wet soils which our most valuable species delight in; for instance the peduncled oak, the ash, elm, hornbeam, spruce fir, alder, &c.

SEASON FOR SOWING.—As a general rule the most favourable moment for sowing is that indicated by the shedding of seed. It is a natural indication which it is useful to follow, but which it is not

---

touched; and in wet lands and cold climates it has the advantage of keeping down the heather, which tends to render the soil peaty and too acid for forest vegetation.

always possible to imitate. Indeed it must not be forgotten that the price of seed forms an important, sometimes the most important, item of expenditure. It is therefore impossible to scatter seed as abundantly as Nature does. Besides this, these seeds are not placed under conditions favourable for resisting frost, while the ravages of those animals, of which they constitute the food, are another danger to their preservation. This last danger is greatest for acorns, beech-nuts and chestnuts, which ripen and fall in autumn, but germinate only in spring, and are greedily sought after by wild pig and the small rodents. Hence it is necessary to keep them until spring according to the methods described in a former section. As for the seeds of the elms, the birch, alder and other species, which it is impossible to keep, they must be sown immediately after they are shed. Hornbeam and ash seeds do not generally germinate until the second spring after their dissemination. They ought to be kept in pits until then, in order to avoid the risk of seeing the soil overgrown with grass, which they fear exceedingly, and which is abundant in the soils which they affect, viz., very moist soils.

As for conifers, sowing in spring generally agrees with natural indications. Indeed, with the exception of the silver fir, which sheds its seed in autumn, and of the spruce fir, which possesses the same characteristic in favourable aspects, the other indigenous conifers scatter their seed during the first warm days of spring. But seeds of the spruce keep very well; those of the silver fir, however, are easily

spoilt by handling and transport, and are, therefore, often advantageously sown at once.

Spring sowing is thus the general rule.* It is also justified by the fact that the seeds germinate before the ground is covered with grass, and that, in the case of conifers, they escape the ravages of birds of passage, which greedily devour them. It is even advisable, in nurseries for example, to sow rather late, only in that case the seeds ought to be soaked in water, or better still, in liquid manure. Nevertheless when large areas are to be sown, it becomes necessary to distribute the work, and thus to sow in autumn as well as in spring. The seeds should then be sown more abundantly, in order to provide against accidents.

MANNER OF SOWING.—When the whole surface of the ground has been cultivated, the seeds are usually sown broad-cast; but when they are small, it is desirable to mix them with fine earth, in order to scatter them more uniformly. The use of dibbling machines with the object of economising seed, seems a difficult matter, and, in the majority of cases, the slope of the ground does not admit of it.

In band and patch cultivation also the seeds are sown with the hand; but in the case of light seeds, care must be taken to stoop down during the operation, in order to avoid their being carried away by the wind to the portions left intact. Too much seed must not be taken in the hand at a time, and they ought to be allowed to slip through between the

* In some parts of the Himalayas it has been found better to sow conifers in the autumn.

thumb and forefinger, in order to distribute them equally and in proper proportions.

In every case it is proper to regulate the quantity of seed used, so as to have no excess or deficiency at the end of the operation. For this purpose the ground and the total quantity of seed should be divided into the same number of equal portions; in this manner the quantity sown is equally distributed from the beginning.

The seeds being scattered, it now remains to cover them. This is done with a harrow, a rake, or a bundle of thorns, according to the nature of the seeds, the depth to which they must be covered, and the method of cultivation employed. When the harrow is used, the length of the teeth is regulated by interlacing flexible twigs between them. The depth to which the seeds ought to be covered varies from one inch to the tenth of an inch according to their size, the amount of moisture necessary for their germination and the hardness of their pericarps.

Occasionally the seeds are sown without cultivating the ground by any of the methods described above. With a hoe or dibbler, holes of a certain depth are made in the ground at regular intervals, and one or two seeds are put into each, and covered over with fine earth or pressed in with the foot. This method is adopted when the quantity of seed available is small, or when the object in view is to restore a species in small blanks in the midst of thickets of very young seedlings.

QUANTITY OF SEED.—The quantity of seed to be used depends in the first place on its quality. To ascertain whether the seeds are good, they are

opened, if large enough, with a penknife, and examined; the kernel ought to completely fill the cavity of the shell, it should be white (except in the ash, in which it is bluish, and in the maple, in which it is green), and moist, and the plumule should be entire. If the seeds are small, they ought, on being crushed with the nail, to leave traces of moisture more or less milky, and in the case of conifer seeds, to emit the odour of turpentine. The weight also furnishes an indication for the quantity of seed to be employed; but nothing beyond the average weight can be given. This has been already done. In sowing by weight, the seeds, if small, should be examined, to see if no dust is mixed up with them; for this purpose it is well to stir them about before weighing.

As the Scotch pine is frequently used, it is necessary to be on one's guard against a fraud often practised in commerce, which consists in adulterating it with spruce fir seeds dyed black. The only sure method of detecting it is by sowing a sufficiently large quantity of the seeds; the young Scotch pine has five or six cotyledonary leaves and a reddish stalk, the spruce fir a yellowish stalk and eight or nine cotyledonary leaves. This precaution is all the more necessary because the pine is generally raised as a transitory crop to restore deteriorated soils or to introduce, later on, under its shelter, some delicate species which could not be grown in the open.

If two-thirds of the seeds are good, the whole lot may be considered as of good quality.

The quantity of seed to be used depends also on the way in which the ground has been cultivated. It is evident that, proportionately more seed is

necessary in band cultivation than when the entire surface of the soil is cultivated, and more for the patch than the band method of cultivation. The intervals between the bands and patches having been determined by the distance desired between the two adjacent plants, no room ought to be left for failure.

Lastly, the season of sowing must be taken into account, as well as the various causes of destruction to which the seeds are exposed. Thus sowing ought to be thicker in autumn than in spring.

In ordinary circumstances, the following figures calculated for an acre may be adopted:

Trees.	Broad-cast.	Bands.	Patches.
	Bushels		
Oak	11	9	6
Beech	9	7	3
	Pounds avoirdupois		
Elm	18	13	...
Hornbeam with the wings	40	31	22
„ without „	36	27	18
Silver fir with „	...	36	...
„ without „	...	31	...
Spruce fir with „	11	9	...
„ without „	9	6	...
Scotch fir with „	9	6	5
„ without „	6	5	4
Austrian and Corsican pines without wings	11	9	6
Cluster pine with wings	13	11	...
„ without „	11	9	...
Larch with „	...	15	...
„ without „	...	11	...

Drying Houses for Conifer Seeds.—It now remains to examine the process of extracting the seeds of the conifers from the cones which contain

them. For this there are two principal methods: (1) by natural heat, or (2) by artificial heat. The first is to be preferred as it approaches more nearly the method adopted by nature, and by it the seeds retain their vigour better. The cones are spread out on sheets and exposed to the sun, and when the scales open, they are violently shaken till the seeds fall out. But by this method many of the seeds still adhere to the cones, and there is complete exposure to all the changes of the weather during the drying; moreover, the process is long, and requires a good deal of room. It is for this reason that the second method is preferred.

Various kinds of drying houses have been constructed. We proceed to describe one which has yielded the best results so far as the quality of the seeds is concerned, and by which also large quantities can be obtained at once. On the ground-floor is established a hot air stove with conduit-pipes which lead into a close room on the first floor. The heated air strikes against a large cast iron cap, which prevents the seeds from falling into the pipes. On the floor are placed movable frames, with canvas bottoms to receive the seeds. Above these, other movable frames or sieves are supported one above the other; the bottom of these is formed of wire netting with rather large meshes, and they are intended to receive the cones. Lastly, draught chimneys are constructed in the corners; they open on a level with the floor, and may be opened and closed at pleasure. For the working of the frames as many little doors are made in the wall of the adjoining room as there are

rows of frames, and frames in each row. The sieves are capable of sliding horizontally in grooves, and are furnished below with rollers to facilitate this motion. Thermometers suspended inside constantly permit of the regularisation of the temperature.

It is very easy to understand the working of the apparatus. The sieves are filled with cones, and all the little doors closed. The stove is heated, generally with empty cones. The hot air fills the room, and as it is constantly renewed, it descends after striking the roof, and escapes by the chimneys carrying the watery vapour along with it. The draught is increased or lessened at pleasure by widening or narrowing the mouth of the chimneys. The scales gradually open. From time to time each little door is opened, and the cones are shaken about by pulling the frames to and fro; and the seeds fall eventually into the lowest row of frames. When the cones are quite open, they are taken out and replaced by fresh ones; thus the process is continuous. The temperature of the close room is regulated by means of the thermometers, as it is essential not to exceed a certain degree of heat, otherwise the vitality of the seeds would be destroyed. For pines and the spruce fir, the temperature may be allowed to rise as high as 40° Centigrade; for larch the temperature is lower, and should be increased only gradually; otherwise the resin in the cones would melt and glue the scales together, thus preventing the seeds from falling out.

If, on taking out the cones from the close room, it is found that the lower scales are not properly open, which is nearly always the case, the remain-

ing seeds may be extracted by threshing the cones with a flail or by some other means. But it is seldom worth while obtaining these seeds, because they are generally barren.

Cones ought to be gathered with the hand, and not by shaking the tree, which does them considerable damage. The gathering is begun as soon as the cones are ripe, *i.e.*, at the end of autumn and during the whole of winter. Cones gathered in spring and those picked up from the ground are, generally speaking, already open, and the good seeds have already fallen out.

In the silver fir the scales disarticulate and fall naturally with the seeds. Hence it is sufficient to gather the cones some days before their natural dissemination, and to spread them out on the granary floor and stir them about from time to time. The seeds are then separated by riddling.

Whatever the method employed, the seeds are obtained with their wings. This is inconvenient, as carriage becomes more expensive; but above all it prevents the seeds from being scattered uniformly, as they are liable to be carried away by the wind, and it is impossible to judge with any accuracy of the quantity which leaves the hand. Hence the wings should be removed; but this process is fraught with risks when not done by conscientious hands.

In the majority of cases the seeds are deprived of their wings by putting them up in heaps, which are watered and allowed to stand thus until, on forcing the hand in, a sensation of heat is felt. Then by lightly rubbing the seeds together, the wings easily

come off. But by this method the seeds are made to go through the first stage of germination, and a considerable number lose their vitality. When it is desired to avoid running this risk, a sack is filled to a third of its capacity with the winged seeds, and the wings are detached by rubbing them together in the sack. After this it only remains to separate the wings and seeds by winnowing.

Do what one will, it is almost impossible to free silver fir seeds entirely of their wings. This strongly adhering membrane inevitably breaks short, leaving a certain portion behind. We have also mentioned above that these seeds do not stand such manipulations. Hence it is safer to use the winged seed.

When the seeds have been extracted from the cones, they ought not to be heaped up at once in the seed room. They should previously be spread out and stirred about with a shovel for several days. It is only after this operation that they can be put up in higher heaps, and even then they must be stirred about once a fortnight. The store-rooms ought to be situated in a cool place, which, however, is not damp. They are generally closed sheds adjoining the drying house.

With such precautions, conifer seeds may be kept two or three years. But it must be remembered that they keep better in the cones, and hence if sufficient space is available, they ought to be left in this state, taking care not to heap them up too high and to stir them about from time to time. Nevertheless it is always safer to use newly obtained seeds. Among the rest, there are some seeds which

germinate only in the second spring, and produce sickly plants without any promise. Silver fir seeds cannot be kept beyond one winter.

NOTE.—It is obvious that direct sowing can be resorted to only with hardy species: those of a delicate constitution can only be sown where sufficient protection exists, for instance, under standing timber which has been thinned out to the extent required by the primary cutting. This is done when one species is to be substituted for another or a mixture restored which has been destroyed. But it is quite impracticable on perfectly bare wastes. To remedy this defect several methods have been proposed, such for instance, as a previous crop of trees of rapid growth, or the simultaneous sowing of cereals. This latter plan is good for species which require nursing for only a limited period, like the elm for example, which germinates in warm weather; but it would never do for species which require shelter during several years. For these a previous timber crop is necessary, and as the cost of labour is the same in each case preference ought obviously to be given to trees capable of covering the outlay within a definite period. The Scotch pine, the birch, and, in strongly calcareous soil, the black Austrian pine seem to fulfil best this condition. The first two especially possess light foliage, and experience proves that when they attain the dimensions of poles, the shelter of their crowns is very favourable for the introduction of the oak, the beech, and the silver fir under them. The oak, it is true, is not averse either to light or heat, but it is very sensitive to late frosts;

moreover, it ought not to be grown pure, and it is by the method in question that its natural auxiliaries are associated with it. The alder renders the same service in moist and wet lands; it grows rapidly, and yields valuable produce at an early age.

CHAPTER IV.

SLIPS* AND LAYERS.

STOCKING with slips and layers cannot, properly speaking, be termed operations of sylviculture, but rather of horticulture. Nevertheless slipping is preferred to sowing in the propagation of willows and poplars (excluding of course the great sallow and the aspen), to keep up pretty varieties, to reproduce exotics, which are not completely naturalised, like the plane tree, &c. The method of layers is still less used, and could scarcely possess any utility in forests except to re-stock small blanks. In nearly every case planting is to be preferred.

There are two methods of slipping: stake slipping, and slipping with two year old wood.

The first succeeds well only with the large willow, theosier, &c. The stake consists of a branch three or four yards long and about two inches in diameter. It is stripped of all its branches, and cut obliquely at both ends, or at least at its lower end. By this means a larger surface of absorption is obtained, and success is favoured. To put it into the ground, a hole about 20 inches deep is made with a spade, or, in wet soil,

* See footnote on page 204.

with a pick, and it is filled in with fine earth. This method is adopted for growing pollards.

Slipping with two year old wood is employed for the small willows, the poplars, and the plane tree. The slip is a branch of the current year, which is cut off along with a portion of the older branch on which it grows. It is shortened down to sixteen or twenty inches, and the end is cut obliquely. It is then pressed twelve or sixteen inches into the ground. When the soil is light it is pressed in at once; otherwise a hole is made with an iron bar, or the soil is loosened so as to prevent the bark from peeling off. The process is facilitated if the slip is pressed in obliquely. Slipping is often performed in nurseries; here the slips are planted in regular lines after thoroughly loosening the soil.

Propagation by layers consists in bending down a young sapling in such a way as to *lay* it against the ground without breaking it off. It is kept in this position by means of strong wooden hooks driven into the ground, and soil is thrown over the young branches, the extremities of which are turned up vertically. These branches soon take root, and when they are able to nourish themselves independently, they are severed from the parent stem. This is generally done at the end of two or three years. If the tree is too thick to bend without breaking, an incision is made for the purpose, which is covered to prevent the wood from drying up. This method may be used to fill up very small blanks; but it is better to plant, which permits of the introduction of valuable trees where they do not exist.

It will doubtlessly be found that numerous details have been omitted on the subject of artificial re-stocking; but it must not be forgotten that our object is to impart general notions, and not to write a complete treatise on these matters. For this reason the re-stocking of lofty mountain chains ravaged by torrents has been passed over in silence. It should form the subject of a special work.

SUPPLEMENT.

NOTES ON THE FIXING OF THE DUNES AND THE TAPPING OF THE CLUSTER PINE (*P. PINASTER*) FOR RESIN.

[In the summer of 1872, the author, in company with the director of the Forest School and of one of the other professors, paid a visit to the dunes, between Bayonne and la Tremblade, and the following is his interesting account of the methods employed for fixing the dunes, including the treatment of the Cluster Pine for its resinous products.—TRS.]

On the low and sandy coasts between the mouths of the Adour and the Gironde, every tide leaves behind it quantities of fine sand. The sand is continually drifted inland by the wind, and forms moving hills, which sometimes attain a height of 230 feet; these hills, as we should naturally expect, have a gentle inclination on the side of the sea, but descend abruptly towards the interior; sometimes they are long, continuous, and disposed in regular and parallel

lines; at other times they run zigzag. This depends on the form of the coast line. Thus between the Adour and the Gironde the first case presents itself; while near the promontory of la Coubre, where the wind blows from several points, the elevations and depressions are entirely irregular.

It is to these moving sand-hills that the name of *dnnes* has been given. According to information furnished by M. Dutemps du Gric, Conservator of Forests at Bordeaux, it has been ascertained that the average rate of their progression towards the interior is fourteen feet a year, and that the quantity of sand thus brought up is in the proportion of 109 cubic yards for every yard of coast-line. The hollow between two consecutive dunes, called *lette* by the inhabitants of the district, is very variable. It is flat at the bottom and generally marshy when the dunes are devoid of all vegetation.

One can easily conceive the great importance of fixing and utilising these dunes, whose onward march has swallowed up everything before it, and has been a perpetual source of danger to human dwellings, which more than once have had to retire before them.

The first attempt to fix these sand-hills was made with hurdles and certain plants having well-developed roots, such as the *Psamma arenaria*, a *Euphorbia*, *Festuca*, &c. But these succeeded only temporarily. At length the Cluster Pine was tried with all the desired result. This pine is admirably adapted to the locality. It is indigenous in the parts of France possesing a mild climate; its tap-

root penetrates deep into the soil and throws out strong lateral roots which in their turn develop along their whole length numerous secondary roots in a vertical direction. In addition to these valuable properties we may add the abundance and fine quality of its resin.

This pine had long before been employed in the dunes, as is proved by the forest of La Teste, which dates back several centuries. But such attempts were successful only on the dunes in the interior, which were protected by those nearer the sea. It was not till the year 1787, when Brémontier began his labours, that they succeeded in planting up to the seashore. The method used at present for fixing the dunes is described in what follows.

Before any sowing operations can be attempted, it is absolutely necessary to establish a protecting wall, in order to prevent the seeds and young plants from being buried over by the drifting sand. This wall is nothing more nor less than a dune, which is purposely allowed to form, called the *littoral dune*. A continuous line of paling is erected parallel to the coast-line about 100 yards from high-water mark. The paling is constructed of planks five feet four inches long, one inch thick, and from five to six inches broad and pointed at the lower end. These planks are put into a trench sixteen inches deep, and then driven eight inches into the sand, so that when the trench is filled in, forty inches remain above ground. An interval of about an inch is left between two consecutive planks.

The sand is arrested by the paling, and is thus

deposited in the form of an inclined plane sloping very gradually seawards. Some of it passes through the spaces left between the planks, and serves as a sort of backing, thus increasing their stability. When the sand reaches the top of the paling, and begins to cover it, the latter is raised by means of a lever with hooks. In this manner the littoral dune rises higher. This increase in height must be rendered as gradual as possible, otherwise the dune might be washed away by the sea.

To give the dune more stability, a tight-bound fence is erected behind the paling. Stakes six feet four inches in length are driven twenty inches into the sand, and the wattling is at first carried only up to a yard above the ground. The wattling is continued upwards as the dune rises. When the dune reaches the top of the stakes, another fence of the same kind is put up, for the old fence obviously cannot be raised like the paling.

The whole is at length fixed by planting over with the *Psamma arenaria* in tufts of five or six plants twenty inches apart. This grass possesses this important property, that, as the sand covers it, its stalk grows higher and developes numerous adventitious roots, which form a veritable network. An acre requires 120 bundles of this plant, weighing twenty-two lbs. each, besides five lbs. of seeds. The first thing done is to sow the seed broadcast, the operation of planting and the going to and fro of the labourers being enough to press them into the ground.

A running foot of paling costs about eightpence. It lasts on an average five years, when the planks are

made of the non-injected sapwood of the Cluster Pine. The expense of keeping it in repair and raising it is about one penny a year per running foot. The price of a foot of fencing is about three farthings and a half, and a new fence must be put up nearly every year.

If, notwithstanding these precautions, the wind is apt to make breaches in the littoral dune, other rows of paling, making a given angle with the first, are erected on the steep side. At the present day may be seen a littoral dune, in capital order, along a coast line of more than 200 kilomètres reaching from the bar of the Adour to the mouth of the Gironde.

A protecting wall against the wind being once obtained, the moment has arrived for beginning sowing operations on the inner dunes. This is done by scattering broadcast a mixture of the seeds of the pine, the common broom (*Sarothamnus scoparius*), the furze (*Ulex nanus*) and the *Psamma arenaria*. In the operations carried on by the State, the quantity of seed to be used per acre is ninety-eight pounds of the pine, eight pounds of the broom, and three and a half pounds of the *Psamma arenaria*. Over the whole is spread a covering of broom, furze, and other brushwood. One man unties the bundles, while two others spread them out, and a fourth throws on a spadeful of earth at intervals of twenty inches to keep the brushwood down. This covering is essential for preventing the seeds, and especially the sand, from being blown away by the wind. Furze is preferable to the broom, as it yields a richer manure by its decomposition.

The sowing and the spreading cut of the brushwood must be done simultaneously. At the close of each day's work some spadefuls of sand are thrown over the last row of brushwood to enable it to resist the force of the wind. Care must be taken that the last row is spread out evenly and well against the ground, so as to prevent the wind from getting underneath. Without this precaution a single night is sufficient to destroy the work of several days.

The pines, the broom, and the furze come up together; and it has been remarked that the young pines are all the finer for growing along with a large quantity of broom and furze. When these latter are not sufficiently abundant, the covering of brushwood should be carefully maintained, as the protection it affords is necessary during nearly four years. Sometimes indeed it has to be renewed, and its maintenance constitutes one of the principal operations during that period.

The reboisement of the littoral dune itself may often be undertaken at the end of a few years, by forming a new littoral dune nearer still to the sea. In any case the maintenance of a littoral dune is a *sine quâ non;* otherwise every result of previous operations must inevitably be lost by the continual drifting in of new sand.

Such is a brief description of the operations employed in fixing the dunes. They often entail great labour, and the difficulty is sometimes so great that the fixing and stocking of one acre does not cost less than eight pounds. This outlay ceases to appear

considerable, if we balance against it the protection which it affords for all the country behind the dunes. Nearly the whole of it is absorbed by the erection and constant repair of the paling, and this principally by the transport of planks and brushwood over a long length of uneven country formed of deep and yielding sand.

It now remains for me to describe the treatment of the Cluster Pine for the extraction of resin. But before I do so, I must mention that since the dunes have been wooded, the hollows have dried up. It is difficult to say whether this is due to the transpiration of the leaves, or rather to the absorption of the water by the vegetable mould, or whether it is to be attributed to some other cause or causes still unobserved. In consequence it has been possible to restock those valleys where no grazing took place, or in which grazing was forbidden.

It is an established fact that the extraction of resin is never remunerative unless the pine is in its true habitat. It is only in hot and mild climates that this tree is indigenous. It is common on the west coast between the mouths of the Adour and the Gironde. To the north of the latter river, between Royan and Rochefort, its vegetation is less vigorous its wood is less resinous, and it no longer attains its usual size. Moreover, the forests it forms are not so dense. Further north, especially in the valley of the Loire, where plantations of it have, in my opinion, been too largely made, we get completely out of its station. It no longer propagates itself naturally, it is much shorter-lived, its wood is of an extremely

inferior quality, and the extraction of resin does not pay.

The resin is abundant only when the pines are exposed to the full influence of light, are in active vegetation, and possess thick foliage. Accordingly, thinning operations on a large scale are executed as soon as the young pines are six or eight years old. The thinnings are repeated every five or six years till the forest has reached the age of twenty years, at which time there should not be more than 240 to 280 plants per acre. The extraction of resin may now begin on the trees which are to be felled before the end of the rotation of the forest. To this end from 200 to 250 trees are marked out for the next thinning operations which are to be made at the end of five or six years. After another thinning at the age of about thirty years, only 100 or 120 trees are left per acre. This number is progressively reduced to eighty and even sixty until the forest is about seventy or eighty years old. It is now time to begin re-planting operations, if the object of the forest is merely the production of resin.

Restocking is obtained either by artificial planting or sowing, or from the self-sown seedlings which may have come up during the last few years. According to M. Eloi Samanos, sowing is the means usually employed in the Landes. The method he recommends is to trace out parallel lines at intervals of from four to six yards (according to the distance required between two successive plants), to cultivate them deeply over a breadth of at least two feet with a pick or plough, and then to sow five pounds of pine seed per acre, and harrow them in lightly.

During the first thinnings, before the resin-tapping begins, the lower branches of the pines are pruned off, so as to obtain a clean stem of at least sixteen feet. The object of this is to get rid of the dead stumps of branches, which interfere with the continuous flow of resin. Moreover, as the wounds caused by the pruning get covered over by new rings of wood, the operation of chipping off the bark and wood necessary for tapping is greatly facilitated by having an even surface to work upon. Experience goes to justify this removal of the lower branches. These branches must be lopped off close to the stem; but care must be taken not to produce an unnecessarily large wound. Above all it must be borne in mind that a tree can never have too much foliage, and therefore only a few branches ought to be pruned off at a time.

It is easily seen that the thinning and pruning operations leave the soil exposed to the light. The spare foliage of the pine aggravates this condition. Thus a rank vegetation presents itself, consisting of grass, heather, broom, ferns, &c. This is much sought after as bedding for animals and as manure. It is bought up under the name of *soutrage* [German, *Streunutzung*] at an average price of 5d. a cart-load (about thirty seven cubic feet). An acre yields from two to five such loads.

The removal of the scrub is evidently a loss to the soil of the forest, as it prevents the formation of mould. But it facilitates the movements of the resin-tappers, and above all diminishes the chances of forest fires, which make great ravages in those

districts during times of drought. This danger is dreaded to such an extent that lines from thirty to sixty feet wide are cleared through the forests at certain distances from each other, and are kept up by cutting away every five years all the vegetation which may have come up during that interval. In the plantations of recent date, and notably in the dunes, these lines are 1,000 yards apart, and are respectively parallel and perpendicular, so as to form squares of about 250 acres each.

There are two methods of resin-tapping, which in French are termed respectively *gemmage à mort* and *gemmage à vie*. The first exhausts and kills the tree [whence the name], and is adopted only when the tree is to be felled soon after; the second, as may be guessed, has for its object to obtain the resin without causing the death of the tree. In either case, the first thing to be done is to strip off gradually a rectangular strip of bark, beginning at the foot of the tree and going up about four inches; a little wood must also be removed with the bark. The wound thus made is technically called a *quarre* or blaze. The instrument used is a light axe with a curved head and a handle bent at an angle in the direction of the concave face of the head. Once or twice a week the wound is reopened, and it is at the same time lengthened by taking off a fresh strip of bark and wood above it about two-fifths of an inch long. In this manner the wound attains a certain length, which in the forests under the control of the Forest Department ought never to exceed eleven feet. Moreover, in the printed stipulations which

contractors are bound to observe when they purchase the right of resin-tapping, there is a clause which fixes a maximum of five inches for the breadth of the *quarre*, and a maximum of two-fifths of an inch for its depth.

Only one *quarre* at a time ought to be worked in those trees which are not to be felled in the next thinning operations. To prolong their existence, it would even be desirable to make the *quarre* only three inches wide. The same *quarre* is worked for five years by the process explained above of freshening and lengthening the wound. During the first year it is lengthened by twenty-two inches; during each of the three succeeding years by twenty-six inches; and during the fifth year by twenty-eight inches. At the end of this term a new *quarre* is opened, which is worked in the same manner. This process is repeated until within a few years of the felling of the trees so tapped, when the process called *gemmage à mort* is employed.

No tree is tapped in the manner we have just described before it has attained a circumference of three feet. M. Lamarque is of opinion that it would be better at the beginning to work a *quarre* for only four years, and then give the tree rest for one year. The *quarres* when left alone, soon heal up by the formation of new rings of wood and bark. After some time a new *quarre* may be opened in the swelling formed by the bark immediately over the old *quarre*.

The swelling is a sure indication of the existence of an old *quarre* under it, and some old trees may be

seen here and there bearing traces of several of them. It frequently happens that from want of sufficient adherence, the bark separates on each side of the old wounds, the separation being wider at the middle, where also the consequent swelling out of the bark is naturally greater. This phenomenon gives the lower part of the stem the shape of a spindle, and the tree looks as if it would be crushed under its own weight.

In private forests the *quarres* are often allowed to reach a height of thirteen to sixteen feet, and two or three are worked at a time on thick trees. This is a bad practice. If for the time being the tree is made to yield a large quantity of resin, its longevity is materially shortened.

As we have already indicated, *gemmage à mort* is practised only in the case of trees near their maturity, or of those which are to be felled in the very next thinning operations. It is begun as soon as the trees are big enough to hold a *quarre*, in other words, as soon as they have attained a girth of twenty to twenty-four inches. This generally happens at the age of twenty years. The *quarres* are opened in precisely the same manner as in the first process; only they are worked up faster, and several at a time are opened in each tree. Usually a tree treated thus dies in three or four years.

When a new *quarre* is cut or an old one re-opened, the resin oozes out in bead-like drops. A portion of it flows down the wound; the rest, owing to volatilisation, solidifies and forms a crust over the wood. This solid substance is known under the name of

galipot. Formerly the resin was allowed to run down to the foot of the tree, where it was received in a little trough hollowed out in one of the roots or in the sand. Much of the resin was thus lost by absorption in the sand, especially the first year. Little earthenware pots are now used, which are hung along the stem of the tree, and are raised as the *quarre* is worked up higher. To get the resin to flow into the pots, a small curved plate of zinc is lightly driven in an oblique direction into the wood immediately over each pot. The pot is kept in its place by means of a nail fixed under, and on which it rests lightly. To render the waste still smaller, the pot is covered with a thin board, which prevents the loss of the volatile portion of the resin. The resin-tapper examines the pots when he goes round to re-open the wounds, and empties any he finds full. The galipot is scraped off once or twice a year.

The use of these pots and plates of zinc constitutes the method of Mr. Hughes. It requires a heavy outlay at first, but it possesses the advantage of yielding a larger quantity of resin, and that in a purer state. According to M. Samanos the results of this method as compared to former results are as four to three. It is much employed in the Dunes at Cape Breton, Mimizan, Biscarosse and la Teste. But in the district round Dax its use is not so general, while at Mont de Marsan it is still rare. This is a source of much loss. To diminish the waste of resin by absorption in the soil, the tapper makes the same trough serve for several successive *quarres.* They are consequently obliged to cut little canals all

round the foot of the tree leading one and all into the same trough. These canals are necessarily cut right into the wood, and thus soon kill the tree.

Resin-tapping is carried on only in the interval between the 1st March and the 15th October; but the gradual thinning off of the bark is begun as early as the 10th February.

Resin is most abundant in trees which measure at least sixteen inches in diameter. A pine of this size yields annually three litres by the process of *gemmage à vie*. Taking into consideration the continual diminution in number of the trees, we may reckon that an acre yields annually about thirty gallons, whatever be the age of the forest. It is not so easy to calculate the yield by the process of *gemmage à mort*. Still it is generally admitted that from eighty to a hundred pines eight inches in diameter will also yield annually the same quantity, and that for three years. On the estate of M. Marcellus, near Biscarosse, I saw a pine thirteen feet in girth and thirty-six feet high up to the first branch, which had ten *quarres* worked on it simultaneously, and which still yields seven or eight litres of resin annually.

The price of the raw resin is necessarily very variable. Sometimes it is as low as 40 francs a *barrique* (340 litres). During the American war it rose to 290 francs. At Mont de Marsan, where it is converted into the different resin products of commerce, the actual price of a *barrique* is 120 francs.

The resin-tapper is paid so much per *barrique*, usually from 30 to 35 francs; which gives an average of four or five francs a day.

I visited at Mont de Marsan several distilleries. In one of them they distil the resin for spirits of turpentine. The raw resin always contains, according to the care with which it has been collected, a greater or less quantity of impurities, such as lumps of earth, chips of wood, bark, leaves, &c. To remove these the resin is put into boilers, in which it is subjected to a temperature just high enough to liquify it without causing it to volatilise. In this liquid state it is passed through sieves of rye-straw into troughs. The clear liquid is known under the name of *térébenthine*. From the troughs the térébenthine is conducted through apipe supplied with a stopcock into a still. During the distillation, a thin continuous stream of water is introduced into the retort by means of a funnel. The water, in the state of steam carries over with it the spirits of turpentine, and after condensation in the worm they are both received into a vat. They are then separated by the process of decantation. Colophony and black and white rosin are made from what remains in the retort. A conduit-pipe leads this residue into a trough, whence it is passed through a very fine brass sieve into a wooden chest; what is collected in the chest is colophony; what is left behind in the sieve is black rosin. It is made into cakes of from 100 to 200 lbs., by pouring it while liquid into troughs hollowed out in fine sand. White rosin is prepared in the same way, except that the hot residue in the sieve is agitated briskly in one-tenth its volume of water before it is poured out into the sand moulds.

All these products have their special industrial

uses. Spirits of turpentine are employed in medicine, in the preparation of varnishes and paints, for lighting, for cleaning furniture, &c. The solid products enter into the manufacture of paper, soap, stearin candles, torches, sealing-wax, &c., and are also used for the calking of vessels.

The residue from the first filtration of the crude resin is burnt in special stoves, and yields tar and pitch.

One barrique of crude resin gives 100 kilos. of spirits of turpentine, which, taking actual prices, would be worth about 125 francs; the other products cover all expenses and yield besides a trifling profit. Black rosin sells at the rate of eighteen francs per hundred kilogrammes; the price of the same weight of white rosin is twenty francs.

In another establishment in the same town, the black rosin is heated to a high temperature, by which a double decomposition takes place. The result is, according to the manipulations employed, the separation of certain volatile oils used in varnishes, or of certain fixed oils which are used for lighting, for making wheel-grease, for impregnating wood, in the manufacture of printing-ink, &c.

Such are the products which have hitherto given their chief value to forests of the Cluster Pine.

Nevertheless, in those districts where means of transport exist, the timber acquires a certain value. Opinions are still divided as to which trees yield the best timber, those that have been tapped for resin, or those left to themselves. It may be observed that the process of tapping produces an outward

flow of resin in the direction of the wound; owing to volatilisation, the tissues become impregnated with solid resin, which increases the durability of the sap-wood. Moreover, since the annual rings of a tapped tree grow less thick, there is a large proportion of autumn wood.* But no fair comparison can be made, as it is rare to find a pine which has not been tapped. Such are the pines which are left as boundary marks; they attain a great size, but are usually felled only when they are in full decay.

It is evident that in the portion of the stem along which the *quarres* have been worked, the annual rings of wood are neither continuous nor regular. Hence it is useless for planking; but it is split up into vine props, which are much esteemed for their durability: the solid resin, with which it is thoroughly impregnated, prevents decay; moreover, it often yields small staves for casks which are to hold the solid resin products. The upper portion of the bole, however, contains timber with continuous rings of wood. At Cape Breton I saw planks seven feet long by seven inches broad and an inch and a quarter thick, made from this portion of the tree. A hundred such planks would contain over forty cubic feet of wood. The hundred are sold for £2 16*s*.

This Pine is also used for making railway sleepers. When impregnated, they are worth 1*s*. 8*d*. each, delivered at the railway stations. To demonstrate their importance, it is enough to observe that the railways in the south of France and in the north of Spain are constructed of this pine.

* According to the law of growth in coniferous species; see note on p. 86.

Moreover, this pine yields a certain quantity of charcoal, which is used locally for metallurgic purposes. A cubic mètre of it weighs from 200 to 220 kilos., and sells for eighteen or twenty francs the kilo.

We have here evidently very valuable resources, which only require the establishment of means of communication to be developed. These do not exist, at least so far as the dunes are concerned; and this state of things must continue as long as the plantations that have been made are not old enough to attract purchasers. Then alone will good roads be made, which will perhaps enable us to grow this pine there as well for its wood as for its resin.

The cultivation of the Cluster Pine has already rendered incalculable service to the surrounding country. It has reclaimed a considerable extent of low lying marshy lands, that used to be the centre of pestilential diseases which decimated the population; it has drained them, it has converted them into productive districts, and has introduced trade and comfort, where poverty and wretchedness seemed to be the unalterable lot of the inhabitants. It has arrested the drifting dunes, which used to be a perpetual menace to fields and habitations. The good it has done can yet be increased. In the department of the Landes alone the extent of land reclaimed by forest culture is estimated at nearly 2,000 square miles; it is about as much in the department of the Gironde; and very soon the treeless moors as well as the naked dunes will only be remembered as things of the past.

In concluding these very incomplete notes, I will

draw the reader's attention to a disease which has been observed in some of these forests. Not unfrequently a pine withers and dies. Starting from the pine as centre, the disease spreads all round over a circular area of an ever-increasing radius. I was not able to investigate its cause. In la Sologne it had been pointed out to me by persons who ascribed it to causes more or less imaginary. May not the disease be traced to a fungus which attacks the woody tissue itself? The circular area over which it propagates itself leads to this supposition, which is strengthened by the means adopted to combat it. In the department of the Landes the progress of the disease is effectually stopped by digging a trench twenty-seven inches deep all round the portion of the forest so attacked.

NOTE. [TRS.] The Baltic Coast is lined with dunes in every respect similar to those of the Coast of Gascony. According to Oberförster Gumtau, of Stettin, works for fixing these moving sand-hills were begun as early as the fourteenth century. Neglected or even totally abandoned, especially during the Thirty Years' War, they have just been resumed in order to protect the country in the interior. The littoral or anterior dune is principally fixed with plants possessing spreading roots and sending up suckers, such as the *Psamma arenaria*, &c., grasses which are planted in square sods of four mètres side in the form of the squares of a chess-board; so that the lines are respectively perpendicular and parallel to the direction of prevailing winds (N.W.). As to the inside

dunes, they are planted up with furze, which has been completely successful, and with the Scotch pine two or three years old. The pines are not put out singly, but in tufts, or rather in sods, like turf, which fit exactly into the holes. Spades of a special pattern are employed both to cut up the sods and to prepare the holes. The cost is on an average three guineas an acre inclusive of the covering of branches of pine, furze and broom, which must be strewn over the transplants for protection. It would appear that the fixing of the Baltic dunes is attended with greater difficulty than the analogous operations on the Gascon Coast where the Cluster Pine is pre-eminently adapted to the soil, and is a very hardy grower.

LIST OF SPECIES MENTIONED IN THE COURSE OF THE WORK.

Hard Woods.

Systematic Name.	Authority.	English Name.
Quercus pedunculata ...	Ehrh.	British or peduncled oak
„ sessiliflora ...	Smith	Sessile-flowered oak
„ Suber	Linn.	Cork „
„ Ilex	„	Holm „
„ coccifera ...	„	Kermes „
„ Tozza	Box.	Pyrenean „
Fagus sylvatica... ...	Linn.	Common beech
Carpinus Betulus ...	„	Hornbeam
Fraxinus excelsior ...	„	Ash
Ulmus campestris ...	Smith	Common elm
„ montana ...	„	Wych or Mountain elm
„ effusa	Wild.	?
Acer Pseudoplatanus ...	Linn.	Sycamore or great maple
„ campestre... ...	„	Common maple
„ platanoïdes ...	„	?
Betula alba	„	Birch
Castanea vulgaris ...	Lamarck.	Sweet chestnut
Pyrus, Malus	...	Fruit trees
Sorbus, Pyracantha, &c.		
Amygdalus, Cerasus ...	...	...
Prunus, &c.		

Soft Woods.

Alnus	Tournef.	Alders
„ glutinosa ...	Linn.	Common alder
„ incana	D. C.	White „
Populus	Tournef.	Poplars
„ tremula... ...	Linn.	Aspen
Tilia	„	Lime or linden trees
Salix	Tournef.	Willows
S. Caprœa	Linn.	Common sallow
S. viminalis	„	Osier

Conifers.

Systematic Name.	Authority.	English Name.
Abies pectinata... ...	D.C.	Silver fir
„ excelsa	„	Spruce „
Pinus sylvestris ...	Linn.	Scotch fir or pine
„ Laricio	Poiret.	Corsican „
„ austriaca... ...	Höss.	Austrian „
„ Pinaster... ...	Solander.	Cluster „
„ cembra	Linn.	Cembran „
„ uncinata... ...	D. C.	Mountain or dwarf pine
„ halepensis ...	Mill.	Aleppo pine
Pinus Strobus	Linn.	Weymouth pine
Larix europæa	D. C.	Larch

Inferior species and Brushwood.

Sambucus	Tournef	Elders
Corylus avellana ...	Linn.	Hazel
Cornus	„	Dog wood
Ligustrum vulgare ...	„	Privet
Viburnum	„	Viburnum
Euonymus europæus ...	Linn.	Spindle tree
Frangula vulgaris ...	Reich.	Breaking Buckthorn
Ilex aquifolium... ...	Linn.	Holly
Buxus sempervirens ...	„	Box tree
Juniperus communis ...	„	Juniper
Rhamnus, Cratægus } various sp.	„	Thorns
Ulex	Linn.	Gorse or furze
Sarothamnus scoparius...	D. C.	Broom
Vaccinium Myrtillus ...	„	Bilberry
Psamma arenaria ...	R. and S.	Marrem grass
Euphorbia	Linn.	Spurge
Festuca	„	Fescue grass

INDEX.

A

B

C

D

T

E

F

G

H

I

L

O

P

Q

R

S

T

U